EXHIBIT M

Exhibit A-31 Invalidity Claim Chart for U.S. Patent No. 7,924,802 vs. IEEE Std. 802.11-2007

IEEE Standard 802.11-2007 ("802.11-2007") was completed in March 2007 and published in June 2007. 802.11-2007 anticipates asserted claims 1–4, 6–10, 13, 14, 17, and 21–24 of U.S. Patent No. 7,924,802 ("the '802 Patent") under 35 U.S.C. § 102. 802.11-2007 also renders obvious asserted claims 1–4, 6–10, 13, 14, 17, and 21–24 of the '802 Patent under 35 U.S.C. § 103, alone based on the state of the art and/or in combination with one or more other references identified in Exs. A-1–A-31, Cover Pleading, and First Supplemental Ex. A-Obviousness Chart.¹

To the extent Plaintiff alleges that 802.11-2007 does not disclose any particular limitation of the asserted claims in the '802 Patent, either expressly or inherently, it would have been obvious to a person of ordinary skill in the art as of the priority date of the '802 Patent to modify 802.11-2007 and/or to combine the teachings of 802.11-2007 with other prior art references, including but not limited to the present prior art references found in Exs. A-1–A-31, Cover Pleading, First Supplemental Ex. A-Obviousness Chart, and the relevant section of charts for other prior art for the '802 Patent in a manner that would render the asserted claims of these patents invalid as obvious.

With respect to the obviousness of the asserted claims of the '802 Patent under 35 U.S.C. § 103, one or more of the principles enumerated by the United States Supreme Court in *KSR v. Teleflex*, 550 U.S. 398 (2007) apply, including: (a) combining various claimed elements known in the prior art according to known methods to yield a predictable result; and/or (b) making a simple substitution of one or more known elements for another to obtain a predictable result; and/or (c) using a known technique to improve a similar device or method in the same way; and/or (d) applying a known technique to a known device or method ready for improvement to yield a predictable result; and/or (e) choosing from a finite number of identified, predictable solutions with a reasonable expectation of success or, in other words, the solution was one which was "obvious to try"; and/or (f) a known work in one field of endeavor prompting variations of it for use either in the same field or a different field based on given design incentives or other market forces in which the variations were predictable to one of ordinary skill in the art; and/or (g) a teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill in the art to modify the prior art reference or to comb ine the

¹ Samsung is investigating this prior art and has not yet completed discovery from third parties, who may have relevant information concerning the prior art, and therefore, Samsung reserves the right to supplement this chart after additional discovery is received. To the extent that any of the prior art discloses the same or similar functionality or feature(s) of any of the accused products, Samsung reserves the right to argue that said feature or functionality does not practice any limitation of any of the asserted claims, and to argue, in the alternative, that if said feature or functionality is found to practice any limitation of any of the asserted claims in the '802 Patent, then the prior art reference teaches the limitation and that the claim is not patentable.

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teachings of various prior art references to arrive at the claimed invention. It therefore would have been obvious to one of ordinary skill in the art to combine the disclosures of these references in accordance with the principles and rationales set forth ab ove.

The citations to portions of any reference in this chart are exemplary only. For example, a citation that refers to or discusses a figure or figure item should be understood to also incorporate by reference that figure and any additional descriptions of that figure as if set forth fully therein. Samsung reserves the right to rely on the entirety of the references cited in this chart to show that the asserted claims of the '802 Patent are invalid. Citations presented for one claim limitation are expressly incorporated by reference into all other limitations for that claim as well as all limitations of all claims on which that claim depends. Samsung also reserves the right to rely on additional citations or sources of evidence that also may be applicable, or that may become applicable in light of claim construction, changes in Plaintiff's infringement contentions, and/or information obtained during discovery as the case progresses.

Claim 1 of the '802 Patent	t Prior Art Reference – 802.11-2007				
[1.1] A method of transmitting information in a wireless communication channel comprising:	To the extent the preamble is limiting, 802.11-2007 discloses "A method of transmitting information in a wireless communication channel comprising." See, e.g.:				

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	$8 + 8 = 16 \ \mu s$ $10 \times 0.8 = 8 \ \mu s$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \ \mu s$ $t_1 \ t_2 \ t_3 \ t_4 \ t_5 \ t_6 \ t_7 \ t_8 \ t_9 \ t_{10} \ GI2 \ T_1 \ T_2$ $GI \ SIGNAL \ GI \ Data 1$ $GI \ Data 2$ $Signal Detect, Coarse Freq. Channel and Fine Frequency RATE SERVICE + DATA DATA$
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[1.2] transmitting first information across a first frequency range using a wireless transmitter, the first frequency range having a first center frequency, a first highest frequency, and a first lowest frequency; and	802.11-2007 discloses "transmitting first information across a first frequency range using a wireless transmitter, the first frequency range having a first center frequency, a first highest frequency, and a first lowest frequency." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only)
	DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,

aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name Type		Description				
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.				
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.				
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.				
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.				
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.				
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).				
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last to a received frame from the PMD receive path to the MAC.				

Name aRXTXSwitchTime aTXRampOnTime aTXRAmpOffTime aTXRFDelay aRXRFDelay aAirPropagationTime	Type integer integer integer integer integer	chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air
aTxRampOnTime aTxRAmpOffTime aTxRFDelay aRxRFDelay	integer integer integer	to Transmit. The maximum time (in microseconds) that the PMD takes to turn the Transmitter on. The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off. The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air
aTxRampOffTime aTxRFDelay aRxRFDelay	integer	Transmitter on. The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off. The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air
aTxRFDelay aRxRFDelay	Integer	Power Amplifier off. The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air
aRxRFDelay		PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air
	integer	
aAirPropagationTime		interface to the Issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-TXEND.indication primitive (for response after SIFS) or PHY-FCCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	Integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10 ³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10 ⁹) + (8 × PSDUoctets) / 10 ⁹) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × N) / 10 ⁹) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin aCWmax	integer integer	The minimum size of the CW, in units of aSlotTime. The maximum size of the CW, in units of aSlotTime.

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007				
	17.1 Introduction				
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.				
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.				
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.				
	See, e.g., 802.11-2007 § 17.1				
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:				
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a				
	reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and				

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NOBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.3.5 af or details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered to 43 and mapped hereafter into OFDM subcarriers as

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007				
	17.3.2.3 Timing related parameters				
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters				
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	N_{SD} : Number of data subcarriers	48	48	48	
	N_{SP} : Number of pilot subcarriers	4	4	4	
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)	
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$	
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$	
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 μ s ($T_{GI} + T_{FFT}$)	
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)	
	$T_{GI\!\!\!/2}$: Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)	
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 $\mu s (T_{GI} + T_{FFT})$	

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007				
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	T _{SHORT} : Short training sequence duration	8 µs $(10 \times T_{FFT}/4)$	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)	
	T_{LONG} : Long training sequence duration	8 $\mu s (T_{GI2} + 2 \times T_{FFT})$	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$	
	See, e.g., 802.11-2007 § 17.3.2.3				

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)^{(c)}} = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \end{cases} \tag{17-4}$ $\sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases}$ In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The
	normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{CUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period
	See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007		
	17.3.2.5 Discrete time implementation considerations		
	The following descriptions of the discrete time implementation are informational.		
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes		

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007		
	17.3.3 PLCP preamble (SYNC)		
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.		
	$8 + 8 = 16 \ \mu s$ $10 \times 0.8 = 8 \ \mu s$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \ \mu s$ $t_1 \ t_2 \ t_3 \ t_4 \ t_5 \ t_6 \ t_7 \ t_8 \ t_9 \ t_{10} \ GI2 \ T_1 \ T_2$ $GI \ SIGNAL \ GI \ Data 1$ $GI \ Data 2$ $Signal Detect, Coarse Freq. Channel and Fine Frequency RATE SERVICE + DATA DATA$		
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize		
	Figure 17-4—OFDM training structure		
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.		

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A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$\mathbf{d} = (\mathbf{I} + \mathbf{j}\mathbf{Q}) \times \mathbf{K}_{\text{MOD}}$			(17-20)
	The normalization factor, K _{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 17-6—Modulation-dependent normalization factor K _{MOD}			
	Modulation K _{MOD}			
	BPSK 1			
	QPSK 1/√2			
	16-QAM 1/√10			
	64-QAM 1/√42			
	See, e.g., 802.11-2007 § 17.3.5.7			

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	17.3.5.8 Pilot subcarriers		
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.		
	See, e.g., 802.11-2007 § 17.3.5.8		

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{cases} N_{SD}^{-1} \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k)\Delta_{F}(t-T_{GI})) \\ N_{ST}^{/2} \\ + p_{n+1} \sum_{k=-N_{ST}^{/2}} P_{k} \exp(j2\pi k\Delta_{F}(t-T_{GI})) \\ k = -N_{ST}^{/2} \end{cases}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

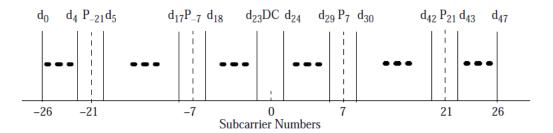


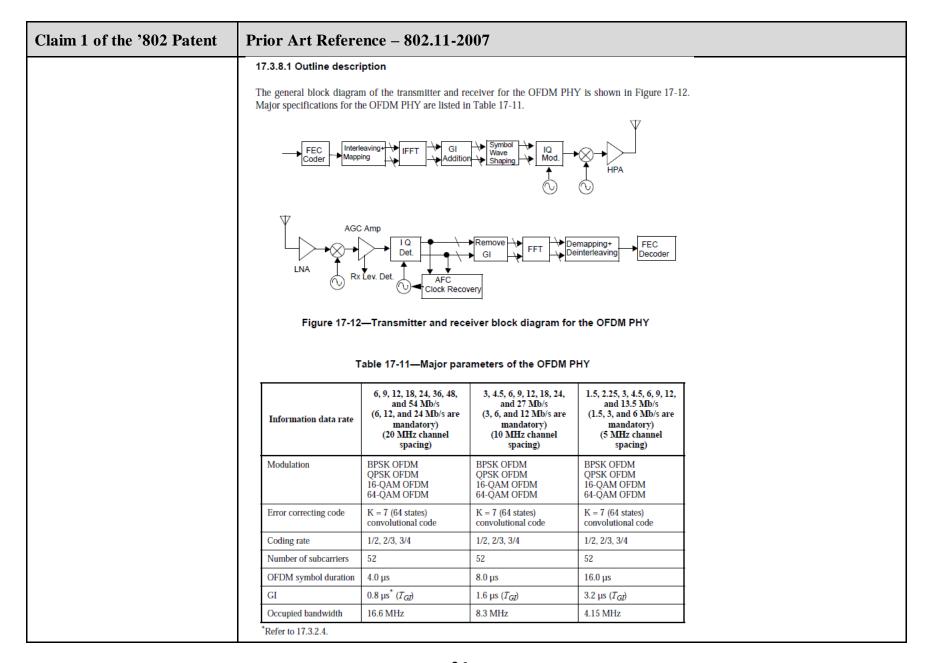
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

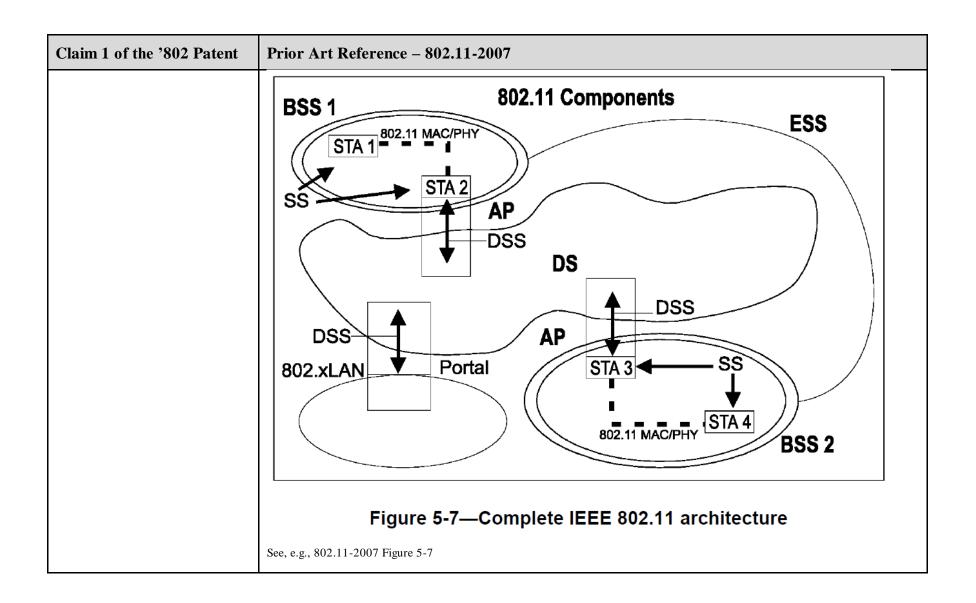
C	Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
		See, e.g., 802.11-2007 § 17.3.5.9

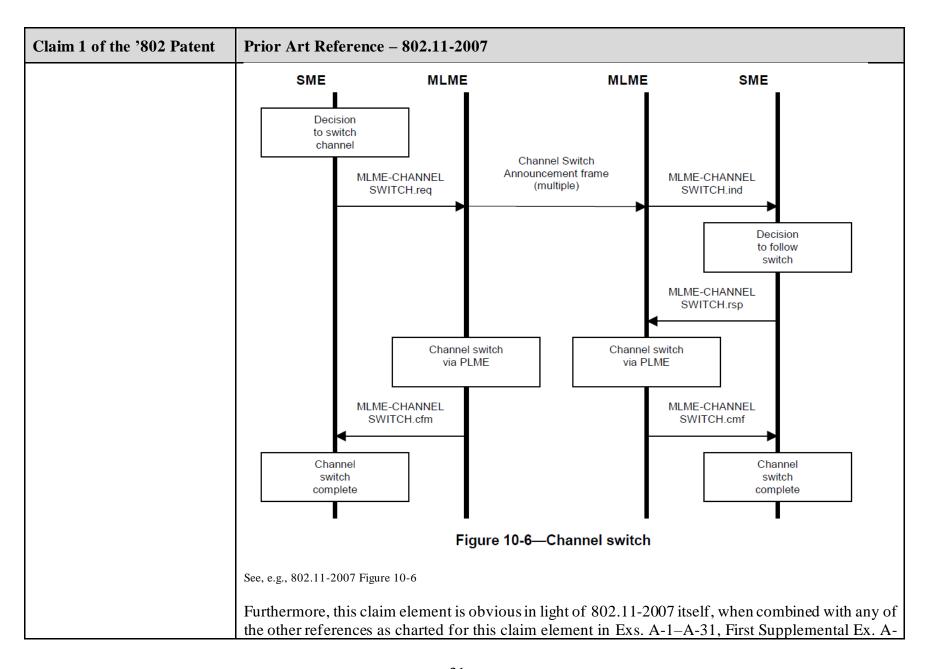


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007 I.2.2 Transmit power levels The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in						
	Table I.5.						
		Frequency band (Maximum output power with Europe (GHz) up to 6 dBi antenna gain) (EIRP)					
		5.15–5.25	40 (2.5 mW/MHz)		200 mW		
		5.25–5.35	200 (12.5 mW/MHz)		200 mW		
		5.470-5.725	_		1 W		
		5.725-5.825	800 (50 mW/MHz)		_		
	Tai	Frequency band (GHz)	U.S. 1	public safety (mV			
	Tal	Frequency band (GHz)	U.S. 1 20 MHz channels	oublic safety (m 10 MHz channels	W) 5 MHz channels		
	Tal	Frequency band	U.S. 1	oublic safety (mV	W) 5 MHz		

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	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBi
	Typical Signal Spectrum (an example) -40 dBr
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





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[1.3] simultaneously transmitting second information across a second frequency range using the	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "simultaneously transmitting second information across a second frequency range using the same wireless transmitter, the second frequency range having a second center frequency greater than the first center frequency, a second highest frequency, and a second lowest frequency." See, e.g.:
same wireless transmitter, the second frequency range having a second center frequency greater than the first center frequency, a second highest frequency, and a second lowest frequency.	 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrmraroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Name aRXTXSwitchTime aTXRampOnTime aTXRAmpOffTime aTXRFDelay aRXRFDelay aAirPropagationTime	Type integer integer integer integer integer	chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air
aTxRampOnTime aTxRAmpOffTime aTxRFDelay aRxRFDelay	integer integer integer	to Transmit. The maximum time (in microseconds) that the PMD takes to turn the Transmitter on. The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off. The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air
aTxRampOffTime aTxRFDelay aRxRFDelay	integer	Transmitter on. The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off. The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air
aTxRFDelay aRxRFDelay	Integer	Power Amplifier off. The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air
aRxRFDelay		PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air
	integer	
aAirPropagationTime		interface to the Issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-TXEND.indication primitive (for response after SIFS) or PHY-FCCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	Integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10 ³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10 ⁹) + (8 × PSDUoctets) / 10 ⁹) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × N) / 10 ⁹) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin aCWmax	integer integer	The minimum size of the CW, in units of aSlotTime. The maximum size of the CW, in units of aSlotTime.

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.1 Introduction			
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.			
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.			
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.			
	See, e.g., 802.11-2007 § 17.1			
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:			
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and			

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NOBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.3.5 af or details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonserambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered to 47 and mapped hereafter into OFDM subcarriers numbered –

Claim 1 of the '802 Patent	Prior Art Reference – 802.1	Prior Art Reference – 802.11-2007			
	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters				
	Value Value Parameter (20 MHz channel (10 MHz channel spacing) spacing) sp				
	N _{SD} : Number of data subcarriers	48	48	48	
	N _{SP} : Number of pilot subcarriers	4	4	4	
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)	
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$	
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$	
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)	
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)	
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	T _{SHORT} : Short training sequence duration	8 µs $(10 \times T_{FFT}/4)$	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)	
	T_{LONG} : Long training sequence duration	8 $\mu s (T_{GI2} + 2 \times T_{FFT})$	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)	
	See, e.g., 802.11-2007 § 17.3.2.3				

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)^{(\ell)}} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GID}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \end{cases} \tag{17-4}$ $\sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases}$ In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The
	normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{CUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period
	See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations		
	The following descriptions of the discrete time implementation are informational.		
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes		

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	$8 + 8 = 16 \ \mu s$ $10 \times 0.8 = 8 \ \mu s$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \ \mu s$ $t_1 \ t_2 \ t_3 \ t_4 \ t_5 \ t_6 \ t_7 \ t_8 \ t_9 \ t_{10} \ GI2 \ T_1 \ T_2$ $GI \ SIGNAL \ GI \ Data 1$ $GI \ Data 2$ $Signal Detect, Coarse Freq. Channel and Fine Frequency RATE SERVICE + DATA DATA$
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

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A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d_0 , are formed by multiplying the resulting (I+jQ) value by a normalization factor d_0 as described in Equation (17-20). $d = (I + jQ) \times K_{MOD} $ (17-20) The normalization factor, d_0 , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.					
	Table 17-6—Modulation-dependent normalization factor K _{MOD}					
	Modulation K _{MOD}					
	'					
	QPSK 1/√2 16-QAM 1/√10					
		64-QAM	1/√42			
	See, e.g., 802.11-2007 § 17.3.5.7					

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	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA} n(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{cases} N_{SD}^{-1} \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k)\Delta_{F}(t-T_{GI})) \\ N_{ST}^{/2} \\ + p_{n+1} \sum_{k=-N_{ST}^{/2}} P_{k} \exp(j2\pi k\Delta_{F}(t-T_{GI})) \\ k = -N_{ST}^{/2} \end{cases}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

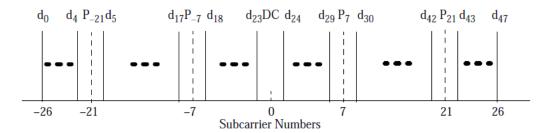


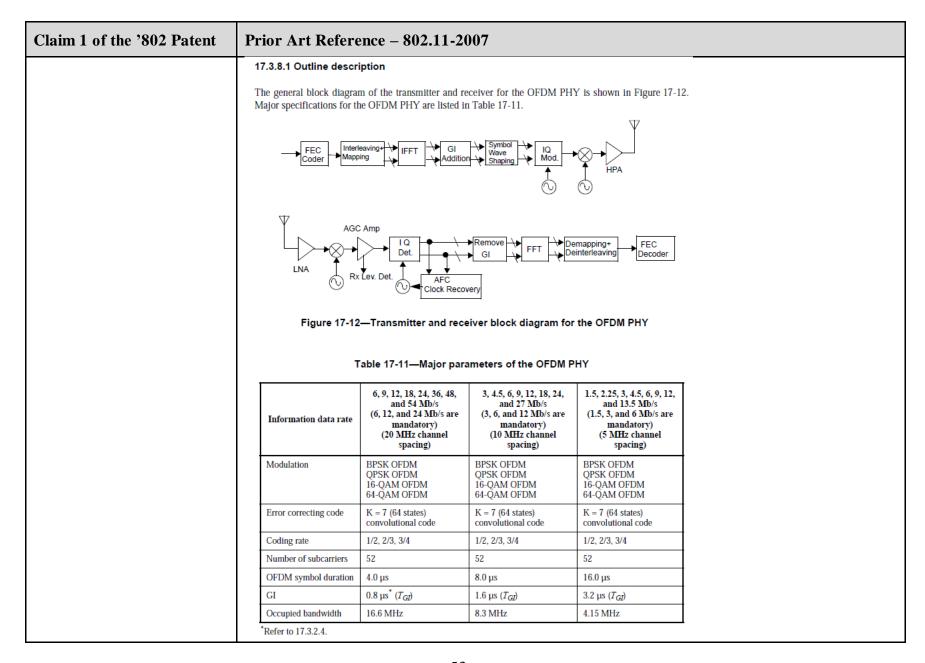
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

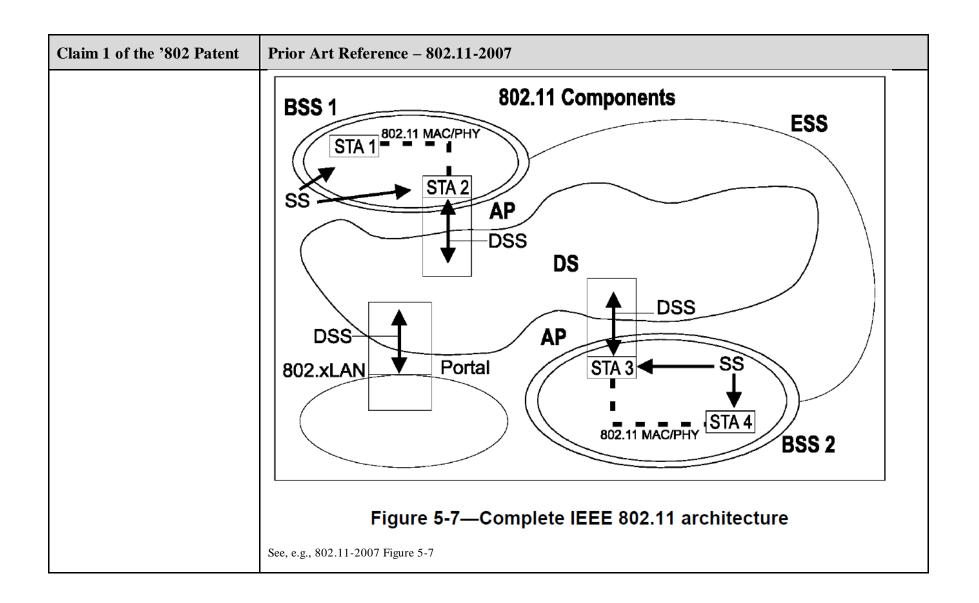
Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007		
	See, e.g., 802.11-2007 § 17.3.5.9		

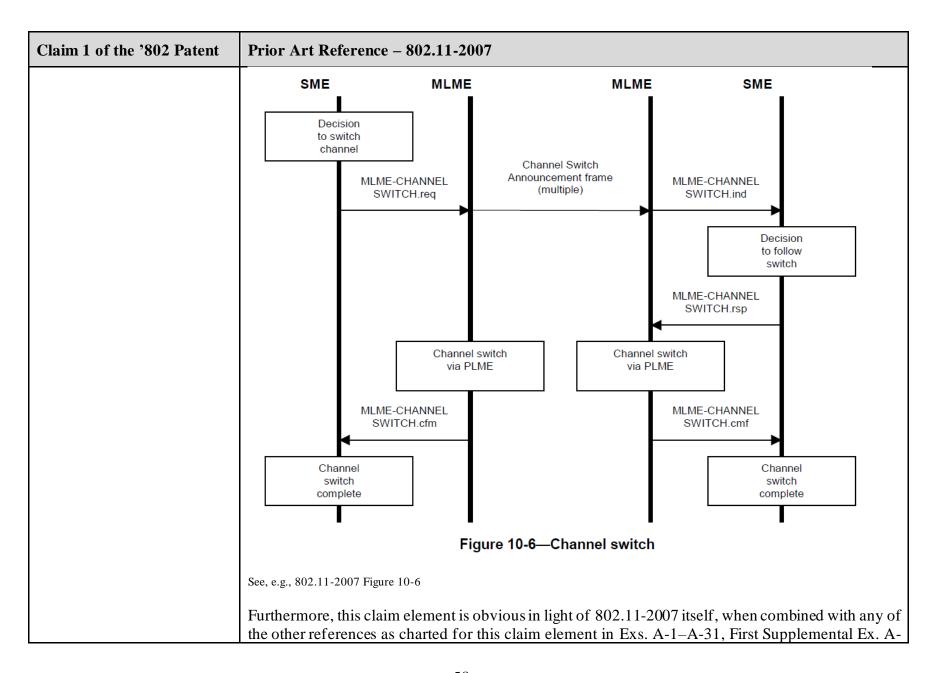


Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007				
	I.2.2 Transmit power leve	els			
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.				
	Table I.4	—Transmit power level by regula	tory domain		
	Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)		
	5.15–5.25	40 (2.5 mW/MHz)	200 mW		
	5.25-5.35	200 (12.5 mW/MHz)	200 mW		
	5.470-5.725	_	1 W		
	5.725-5.825	800 (50 mW/MHz)	_		
	Frequency ba		(mW)		
		U.S. public safety			
	Frequency ba	U.S. public safety 20 MHz	(mW) 5 MHz		

Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 1 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
[2.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.
[2.2] wherein frequency difference between the first center frequency and the second center frequency is	802.11-2007 discloses "wherein frequency difference between the first center frequency and the second center frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range." See, e.g.:
greater than the sum of one- half the first frequency range and one-half the second frequency range.	1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1
	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation
	f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime, aPHY-RX-START-Delay, aRxTxTurnaroundTime, aTxPLCPDelay, aRxPLCPDelay, aRxTxSwitchTime, aTxRampOnTime, aTxRampOffTime, aTxRFDelay, aRxRFDelay, aAirPropagationTime, aMACProcessingDelay, aPreambleLength, aPLCPHeaderLength, aMPDUDurationFactor, aMPDUMaxLength,

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

aCWmin, aCWmax

Name	Туре	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Prior Art Refe	rence –	802.11-2007
Name	Туре	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	Integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	Integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate [aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
Claim 2 of the 802 Fatent	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered to 47 and mapped hereafter into OFDM subcarriers numbered –26 t
	See, e.g., 802.11-2007 § 17.3.2.1

Claim 2 of the '802 Patent	Prior Art Reference – 802.1	1-2007		
	17.3.2.3 Timing related par	ameters		
	Table 17-4 is the list of timing p	parameters associated with	the OFDM PLCP.	
	Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N _{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 $\mu s (T_{GI} + T_{FFT})$
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)
	T _{LONG} : Long training sequence duration	8 μ s ($T_{GIZ} + 2 \times T_{FFT}$)	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(i)} = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \end{cases} $ $\sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ (17-4)
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GI2} + 2T_{FFT}$ T_{GUARD} $= T_{GI2}$ T_{FFT} T_{FFT} T_{TR} T_{TR} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007	
	17.3.2.5 Discrete time implementation considerations	
	The following descriptions of the discrete time implementation are informational.	
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes	

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	$8+8=16~\mu\text{s}$ $10\times0.8=8~\mu\text{s}$ $2\times0.8+2\times3.2=8.0~\mu\text{s}$ t_1 t_2 t_3 t_4 t_5 t_6 t_7 t_8 t_9 t_{10}
	Selection Timing Synchronize Offset Estimation LENGTH Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

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A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ev}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007				
	17.3.5.7 Subcarrier modulation mapping				
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 1 RATE requested. The encoded and interleaved binary serial input dat (1, 2, 4, or 6) bits and converted into complex numbers representing constellation points. The conversion shall be performed according illustrated in Figure 17-10, with the input bit, b ₀ , being the earliest if formed by multiplying the resulting (I+jQ) value by a normalize Equation (17-20).			ded into groups of N_{BPSC} \times , 16-QAM, or 64-QAM constellation mappings, The output values, d, are	
	$d = (I + jQ) \times K_{MOD} $ (17-20)				
	that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.				
	from SIGNAL to DATA, as shown in Figure same average power for all mappings. I normalization factor can be used, as long as t	e 17-1. The purpose of In practical impleme	the normalization tations, an ap	on factor is to achieve the proximate value of the	
	from SIGNAL to DATA, as shown in Figure same average power for all mappings. I normalization factor can be used, as long as t	e 17-1. The purpose of In practical impleme the device conforms w	the normalization intations, an apprint the modulation in the modu	on factor is to achieve the proximate value of the on accuracy requirements	
	from SIGNAL to DATA, as shown in Figure same average power for all mappings. I normalization factor can be used, as long as t described in 17.3.9.6.	e 17-1. The purpose of In practical impleme the device conforms w	the normalization intations, an apprint the modulation in the modu	on factor is to achieve the proximate value of the on accuracy requirements	
	from SIGNAL to DATA, as shown in Figure same average power for all mappings. I normalization factor can be used, as long as t described in 17.3.9.6. Table 17-6—Modulation	e 17-1. The purpose of In practical impleme the device conforms w	the normalization and apprint the modulation and apprint the modulation alization factors.	on factor is to achieve the proximate value of the on accuracy requirements	
	from SIGNAL to DATA, as shown in Figure same average power for all mappings. I normalization factor can be used, as long as t described in 17.3.9.6. Table 17-6—Modulation Modulation	e 17-1. The purpose of In practical impleme the device conforms we n-dependent normal Karaman	The normalization that intations, an appointment of the modulation alization factors	on factor is to achieve the proximate value of the on accuracy requirements	
	from SIGNAL to DATA, as shown in Figure same average power for all mappings. I normalization factor can be used, as long as t described in 17.3.9.6. Table 17-6—Modulation Modulation BPSK	e 17-1. The purpose of In practical implement the device conforms we n-dependent normal K	the normalization that ions, an appoint the modulation alization factors.	on factor is to achieve the proximate value of the on accuracy requirements	

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{cases} N_{SD}^{-1} \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k)\Delta_{F}(t-T_{GI})) \\ N_{ST}^{/2} \\ + p_{n+1} \sum_{k=-N_{ST}^{/2}} P_{k} \exp(j2\pi k\Delta_{F}(t-T_{GI})) \\ k = -N_{ST}^{/2} \end{cases}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

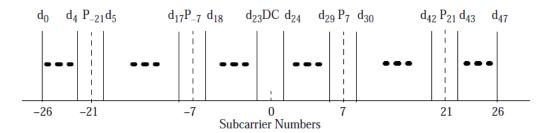


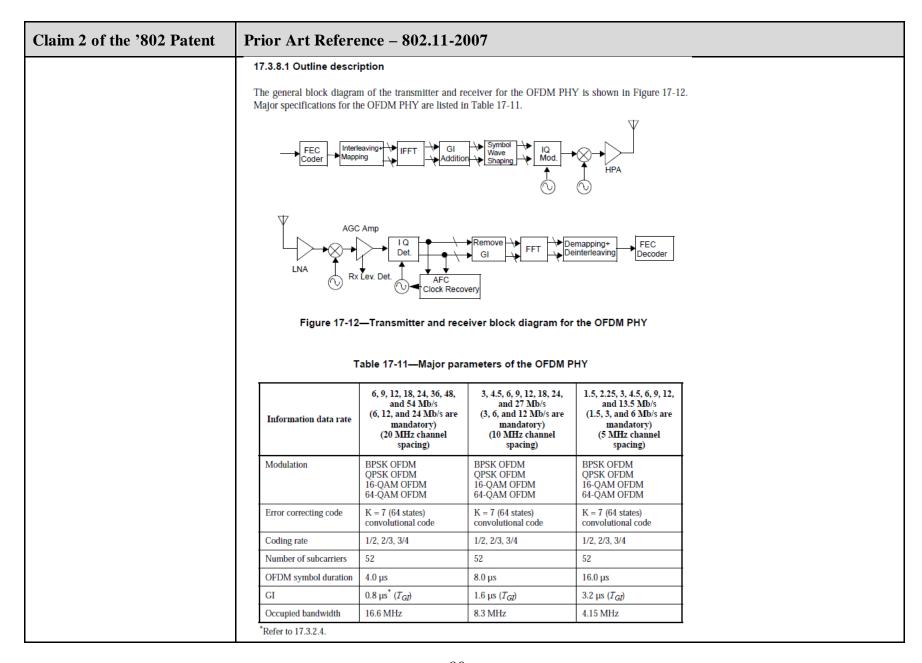
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

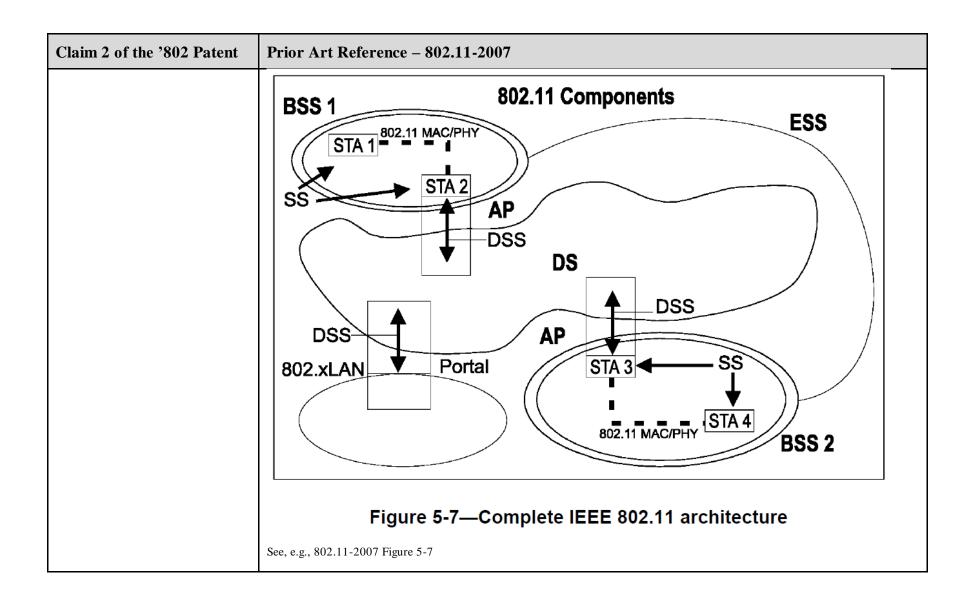
Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

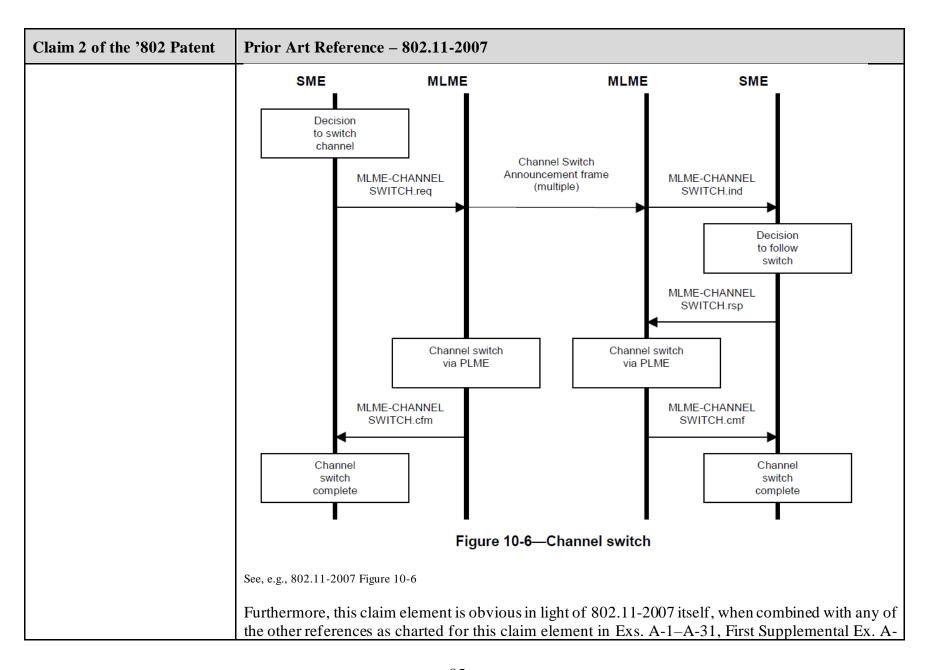


Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007					
	I.2.2 Transmit power levels The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5. Table I.4—Transmit power level by regulatory domain					
					Europe (EIRP)	
	5.15–5.25 40 (2.5 mW/MHz)		200 mW	1		
		5.25-5.35	200 (12.5 mW/MHz)		200 mW	1
		5.470-5.725	_		1 W	1
		5.725-5.825	800 (50 mW/MHz)		_	
	Tal	ole I.5—U.S. public sa	fety transmit po	ower levels by	regulatory domai	n
		Frequency band (GHz)	20 MHz	. public safety (m'	5 MHz	
			1			

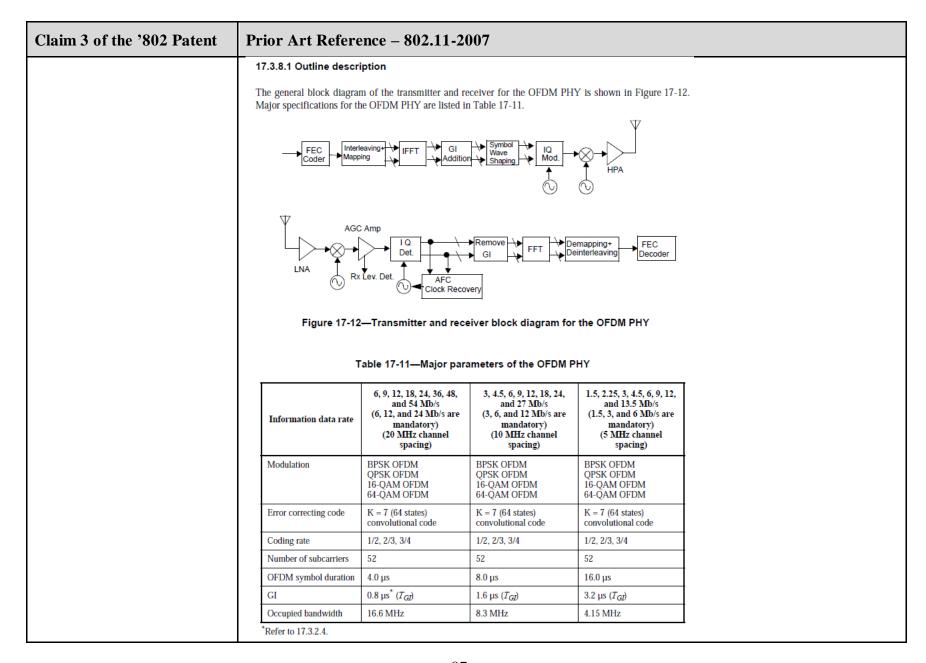
Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 2 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.

Claim 3 of the '802 Patent	Prior Art Reference – 802.11-2007
[3.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.
[3.2] wherein the first and second information are transmitted using the same power amplifier in said wireless transmitter.	802.11-2007 discloses "wherein the first and second information are transmitted using the same power amplifier in said wireless transmitter." See, e.g.:



Claim 3 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same s teps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.4 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits
	return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details.
	h) Divide the encoded bit string into groups of <i>NCBPS</i> bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of <i>NCBPS</i> bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables.
	groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. i) Divide the complex number string into groups of 48 complex numbers. Each such group will be

Claim 3 of the '802 Patent	Prior Art Reference – 802.11-2007
	associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting "complex baseband" waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3).
	Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 4 of the '802 Patent	Prior Art Reference – 802.11-2007
[4.1] The method of claim 3	802.11-2007 discloses all the elements of claim 3 for all the reasons provided above.
[4.2] wherein the bandwidth of said power amplifier is greater than the difference between the first lowest	802.11-2007 discloses "wherein the bandwidth of said power amplifier is greater than the difference between the first lowest frequency and the second highest frequency." See, e.g.:

Claim 4 of the '802 Patent	Prior Art Reference – 802.11-2007					
frequency and the second	17.3.8.1 Outline descr	17.3.8.1 Outline description				
highest frequency.	The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 17-12. Major specifications for the OFDM PHY are listed in Table 17-11.					
	FEC Interleaving IFFT Symbol Wave Addition Shaping Mod. HPA					
	AGC Amp I Q Det. Det. AFC Clock Recovery					
	Figure 17-12—Transmitter and receiver block diagram for the OFDM PHY					
	Table 17-11—Major parameters of the OFDM PHY					
	Information data rate	6, 9, 12, 18, 24, 36, 48, and 54 Mb/s (6, 12, and 24 Mb/s are mandatory) (20 MHz channel spacing)	3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s (3, 6, and 12 Mb/s are mandatory) (10 MHz channel spacing)	1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s (1.5, 3, and 6 Mb/s are mandatory) (5 MHz channel spacing)		
	Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM		
	Error correcting code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code	K = 7 (64 states) convolutional code		
	Coding rate	1/2, 2/3, 3/4	1/2, 2/3, 3/4	1/2, 2/3, 3/4		
	Number of subcarriers	52	52	52		
	OFDM symbol duration	4.0 μs	8.0 μs	16.0 μs		
	GI	0.8 μs [*] (<i>T_{GI}</i>)	1.6 μs (<i>T_{GI}</i>)	3.2 μs (<i>T_{GI}</i>)		
	Occupied bandwidth	16.6 MHz	8.3 MHz	4.15 MHz		
	*Refer to 17.3.2.4.					

Claim 4 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.4 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits
	return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details.
	h) Divide the encoded bit string into groups of <i>NCBPS</i> bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details.
	 i) Divide the resulting coded and interleaved data string into groups of <i>NCBPS</i> bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. i) Divide the complex number string into groups of 48 complex numbers. Each such group will be

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	associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting "complex baseband" waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3).
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2
	Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

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[6.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.
[6.1] The method of claim 1 [6.2] wherein the first information corresponds to a first wireless protocol and the second information corresponds to a second wireless protocol.	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above. 802.11-2007 discloses "wherein the first information corresponds to a first wireless protocol and the second information corresponds to a second wireless protocol." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not

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	possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2 5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.

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	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by

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	regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime, aPHY-RX-START-Delay, aRxTxTurnaroundTime, aTxPLCPDelay, aRxPLCPDelay, aRxTxSwitchTime, aTxRampOnTime, aTxRampOffTime, aTxRFDelay, aRxRFDelay, aAirPropagationTime, aMACProcessingDelay, aPreambleLength, aPLCPHeaderLength, aMPDUDurationFactor, aMPDUMaxLength, aCWmin, aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Туре	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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Name	Туре	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	Integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-TXSTNAT.request primitive pursuant to a PHY-TXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength, + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

cy division multiplexing (OFDM) system. unication capabilities of 6, 9, 12, 18, 24, 36, lata rates of 6, 12, and 24 Mb/s is mandatory. y or quadrature phase shift keying (BPSK or 6-QAM or 64-QAM). Forward error rate of 1/2, 2/3, or 3/4.
sing 10 MHz channel spacings with data Mb/s. The support of transmitting and using 10 MHz channel spacing. The halfclocked (CCA) times when using 10 MHz regarding use of this OFDM system in
n using 5 MHz channel spacing with data 3.5 Mb/s. The support of transmitting and using 5 MHz channel spacing. The quarterclocked 5 MHz channel spacing. The DFDM system in the 4.9 GHz band is in
ich are described fully in later subclauses, as estanding the details of the convergence
s of a "short training sequence" (used and coarse frequency acquisition in fused for channel estimation and fine arval (GI). Refer to 17.3.3 for details. In SERVICE fields of the dLENGTH fields of the PLCP, and are subsequently mapped onto a symbol. In order to facilitate a 6 zero tail bits are inserted into the disymbol follows the same steps for
rv nd d I , a sy

coccoccition of the bits distributed of the bits distr	epending a GI as described subsequently for data transmission with BPSK-OFDM modulated at ding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. Calculate from RATE field of the TXYECTOR the number of data bits per OFDM symbol (NDBPS), e coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded is per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. Append the PSDU to the SERVICE field of the TXYECTOR. Extend the resulting bit string with rob bits (at least 6 bits) so that the resulting length will be a multiple of NBBPS. The resulting bit ring constitutes the DATA part of the packet, Refer to 17.3.5.3 for details. Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and OR it with the extended string of data bits. Refer to 17.3.5.4 for details. Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits turn the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for tails. Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) me of the encoder output string (chosen according to "puncturing pattern") to reach the desired oding rate. "Refer to 17.3.5.5 for details. Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer 17.3.5.6 for details. Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit outps, convert the bit group into a complex number according to the modulation encoding tables. For the data string into groups of 48 complex numbers. Each such group will be sociated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 d dnapped hereafter into OFDM subcarriers a politic string into groups of 48 complex numbers will be numbered of to 47 d dnapped hereafter int

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	17.3.2.3 Timing related par	ameters		
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N_{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 $\mu s (T_{GI} + T_{FFT})$
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	$T_{GI\!\!\!/2}$: Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T _{SYM} : Symbol interval	4 μs $(T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μs (10 × T _{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 $\mu s (10 \times T_{FFT}/4)$
	T _{LONG} : Long training sequence duration	8 $\mu s (T_{GI2} + 2 \times T_{FFT})$	16 μs $(T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$
	See, e.g., 802.11-2007 § 17.3.2.3		•	

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(t)} = Re\{r\langle t\rangle \exp(j2\pi f_c t)\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

In the case of vanishing T_{TE} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TE} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TE} as shown in Figure 17-2. The transition time, T_{TE} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.2 and 17.3.9.2 and 17.3.9.2 and 17.5.1 min domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain fillering. Therefore, the transition shape and duration of the transition are informative parameters. T = T_{GLY} - T_{TET} (a) T_{CLUARD} T_{FET} T_CLUARD T_TEFT T_CLUARD T_TEFT T_CLUARD T_TEFT T_CLUARD T_TEFT T_CLUARD T_TEFT T_CLUARD T_TEFT T_T_CLUARD T_TEFT T_T_CLUARD T_TEFT T_T_CLUARD T_TEFT T_T_T_TEFT (b)	Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007
T_{FFT} $T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} T_{FFT} T_{FFT} T_{FFT} T_{FFT} T_{TR}	Claim 6 of the '802 Patent	$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \end{cases} \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ (17-4) In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)		Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period (a)

Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007	
	17.3.2.5 Discrete time implementation considerations	
	The following descriptions of the discrete time implementation are informational.	
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes	

Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0.80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, Coarse Freq. Channel and Fine Frequency RATE AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{eff}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			ided into groups of <i>N_{BPSC}</i> K, 16-QAM, or 64-QAM d constellation mappings, The output values, d, are
	$d = (I + jQ) \times K_{MOD}$			(17-20)
	The normalization factor, K_{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6. Table 17-6—Modulation-dependent normalization factor K_{MOD}			ion, as the signal changes on factor is to achieve the oproximate value of the
				or K _{MOD}
		Modulation	K_{MOD}	
		BPSK	1	
	QPSK 1/√2 16-QAM 1/√10			
	64-QAM 1/√42			
	See, e.g., 802.11-2007 § 17.3.	5.7		

Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007	
	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8	

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA} n(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

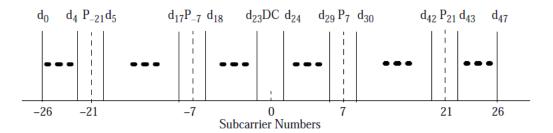


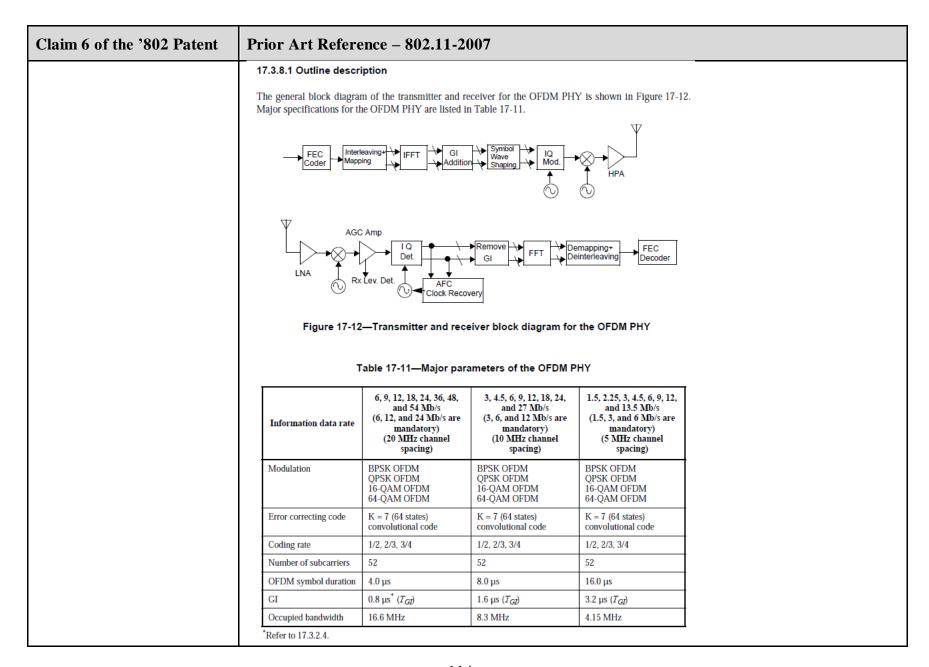
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

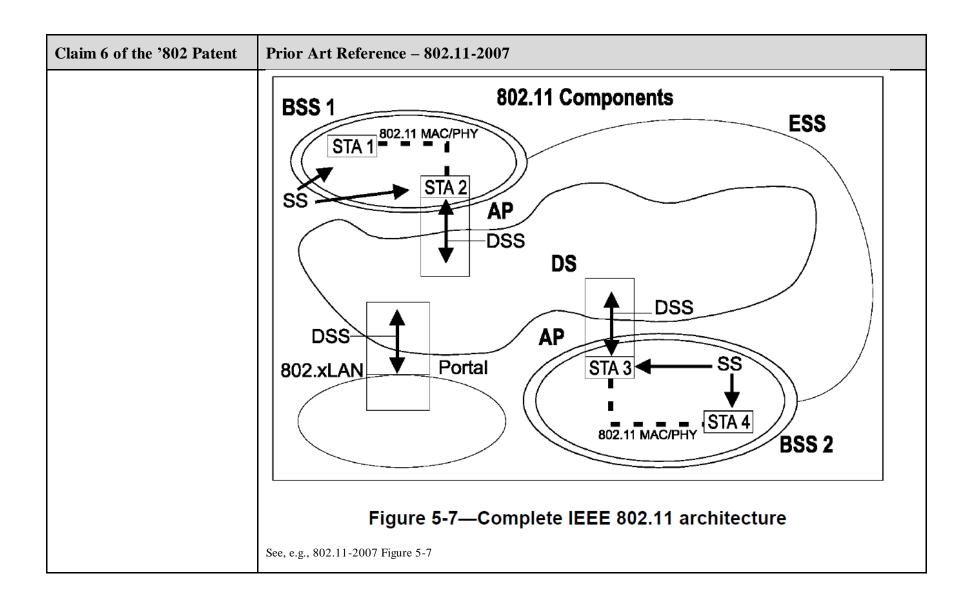
Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

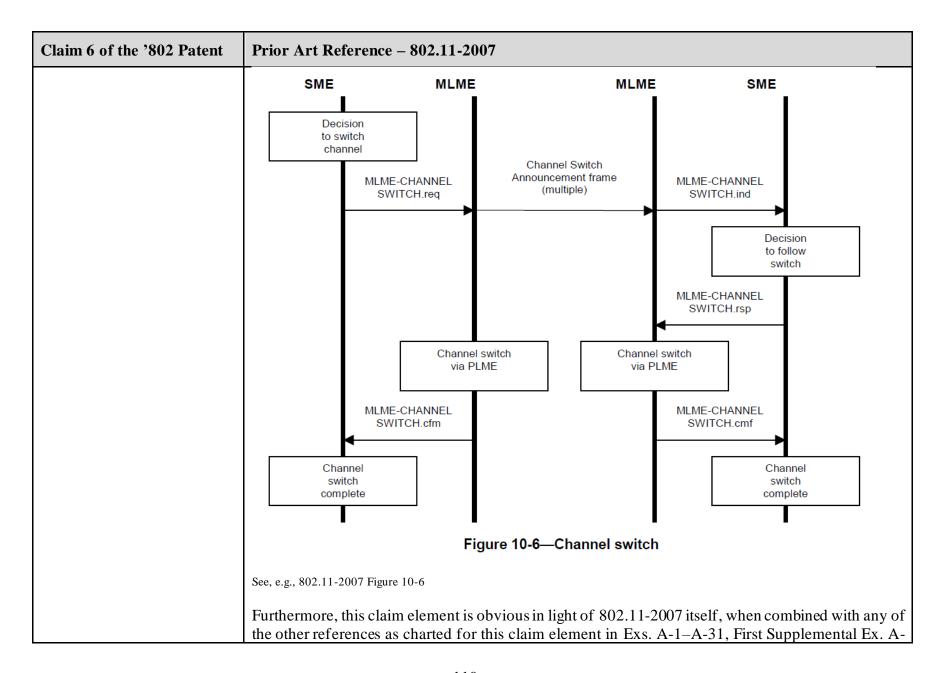


Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 6 of the '802 Patent	nt Prior Art Reference – 802.11-2007					
	I.2.2 Transmit power levels The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.					
	Table I.4—Transmit power level by regulatory domain					
		Frequency band (GHz)	United (Maximum out up to 6 dBi a (m)	put power with ntenna gain)	Europe (EIRP)	
		5.15-5.25	40 (2.5 m	W/MHz)	200 mW	
		5.25–5.35	200 (12.5 r	nW/MHz)	200 mW	
		5.470-5.725	_	-	1 W	
		5.725-5.825	800 (50 m	W/MHz)	_	
	Ta	Table I.5—U.S. public safety transmit power levels by regulatory doma				
		Frequency band	U.S	5. public safety (m\	W)	
		Frequency band (GHz)	U.S 20 MHz channels	5. public safety (m 10 MHz channels	5 MHz channels	
			20 MHz	10 MHz	5 MHz	

Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007	
	I.2.3 Transmit spectrum mask	
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.	
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)	
	Typical Signal Spectrum (an example) -40 dBr	
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)	
	Figure I.1—Transmit spectrum mask	
	See, e.g., 802.11-2007 § I.2.3	





Claim 6 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.

Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007
[7.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.
[7.2] wherein the first information and the second information are the same data transmitted across two different frequencies.	802.11-2007 discloses "wherein the first information and the second information are the same data transmitted across two different frequencies." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs, In IEEE \$18 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance The PHYs used in IEEE \$18 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium
	c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts

Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only)
	DSSs are specified for use by MAC sublayer entities. Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2

Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

a Rx Tx Turnaround Time,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receiv to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	Integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the firs chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTIme. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

duction
e specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. If system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory, and uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
If system also provides a "half-clocked" operation using 10 MHz channel spacings with data ations capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and t data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked doubles symbol times and clear channel assessment (CCA) times when using 10 MHz acing. The regulatory requirements and information regarding use of this OFDM system in ad 5 GHz bands is in Annex I and Annex J.
If system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data ation capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and t data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked quadruples symbol times and CCA times when using 5 MHz channel spacing. The requirements and information regarding use of this OFDM system in the 4.9 GHz band is in ad Annex J.
02.11-2007 § 17.1
Overview of the PPDU encoding process ing process is composed of many detailed steps, which are described fully in later subclauses, as w. The following overview intends to facilitate understanding the details of the convergence
the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used onvergence, diversity selection, timing acquisition, and coarse frequency acquisition in r) and two repetitions of a "long training sequence" (used for channel estimation and fine acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. The PLCP header field from the RATE, LENGTH, and SERVICE fields of the DR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP encoded by a convolutional code at a rate of $R = 1/2$, and are subsequently mapped onto a K encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a d timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the ler. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for

coding ra	ng a GI as described subsequently for data transmission with BPSK-OFDM modulated at te 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. ate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS),
bits per d) Apper zero bits string co e) Initiat XOR it v f) Replace return the details. g) Encode some of "coding h) Divide "interleato 17.3.5 i) Divide groups, or Refer to j) Divide associate and map 8 to 20, inserting with zero k) Four subcarrie l) For ea Fourier t forming applying m) Apper RATE at n) Up-co of the de An illust	grate (R), the number of bits in each OFDM subcarrier (<i>NBPSC</i>), and the number of coded DFDM symbol (<i>NCBPS</i>). Refer to 17.3.2.2 for details. In the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with (at least 6 bits) so that the resulting length will be a multiple of <i>NDBPS</i> . The resulting bit string with a pseudo-random nonzero seed, generate a scrambling sequence, and with the extended string of data bits. Refer to 17.3.5.3 for details. The the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and with the extended string of data bits. Refer to 17.3.5.4 for details. The the extended string of data bits. Refer to 17.3.5.4 for details. The extended string of the data with six nonscrambled zero bits. (Those bits to convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) the encoder output string (chosen according to "puncturing pattern") to reach the desired ata: "Refer to 17.3.5.5 for details. The encoded bit string into groups of <i>NCBPS</i> bits. Within each group, perform an 'ing'' (reordering) of the bits according to a rule corresponding to the desired RATE. Refer 6 for details. The encoded and interleaved data string into groups of <i>NCBPS</i> bits. For each of the bit onvert the bit group into a complex number according to the modulation encoding tables. 17.3.5.7 for details. The complex number string into groups of 48 complex numbers. Each such group will be do with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 bed hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled value. Refer to 17.3.5.9 for details. The group of subcarriers –26 to 26, convert the subcarriers to time domain usin

Claim 7 of the '802 Patent	Prior Art Reference – 802.1	1-2007		
	17.3.2.3 Timing related par	ameters		
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N_{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	$T_{GI\!\!\!/2}$: Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T _{SYM} : Symbol interval	4 μs $(T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μ s (10 × T_{FFT} /4)
	T_{LONG} : Long training sequence duration	8 µs $(T_{GI2} + 2 \times T_{FFT})$	16 μs ($T_{GI2} + 2 \times T_{FFT}$)	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$

Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(i)} = Re\{r\langle t\rangle \exp(j2\pi f_c t)\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{\rm ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \end{cases} $ $\sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GI2} + 2T_{FFT}$ T_{GUARD} $= T_{GI2}$ T_{FFT} T_{FFT} T_{FFT} T_{TR} T_{TR} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	$8 + 8 = 16 \mu\text{s}$ $10 \times 0.8 = 8 \mu\text{s}$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \mu\text{s}$ $t_1 t_2 t_3 t_4 t_5 t_6 t_7 t_8 t_9 t_{10} \text{GI2}$ $T_1 T_2 \text{GI SIGNAL GI Data 1}$
	Signal Detect, Coarse Freq. Channel and Fine Frequency RATE AGC, Diversity Offset Estimation Offset Estimation Selection Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ev}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPS} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mapping illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, as formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			ided into groups of <i>N_{BPSC}</i> K, 16-QAM, or 64-QAM d constellation mappings, The output values, d, are
	$d = (I + jQ) \times K_{MOD}$			(17-20)
	that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6. Table 17-6—Modulation-dependent normalization factor K _{MOD}			on factor is to achieve the oproximate value of the
				or K _{MOD}
		Modulation	K_{MOD}	
		BPSK	1	
		QPSK	1/√2	
		16-QAM		
		10-QAIVI	1/√10	

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	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA} n(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

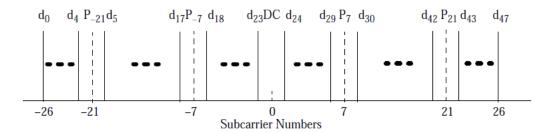


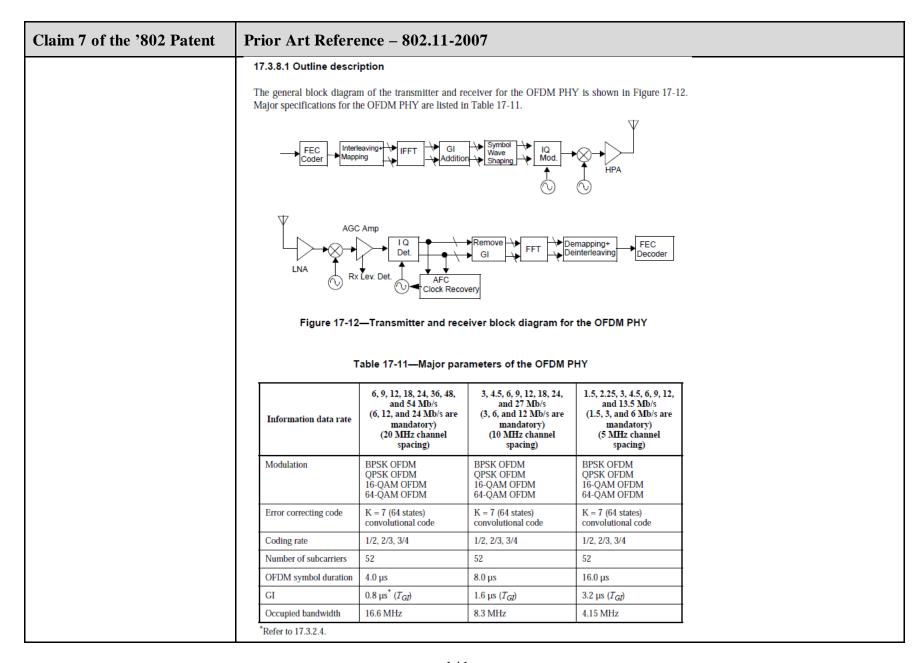
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

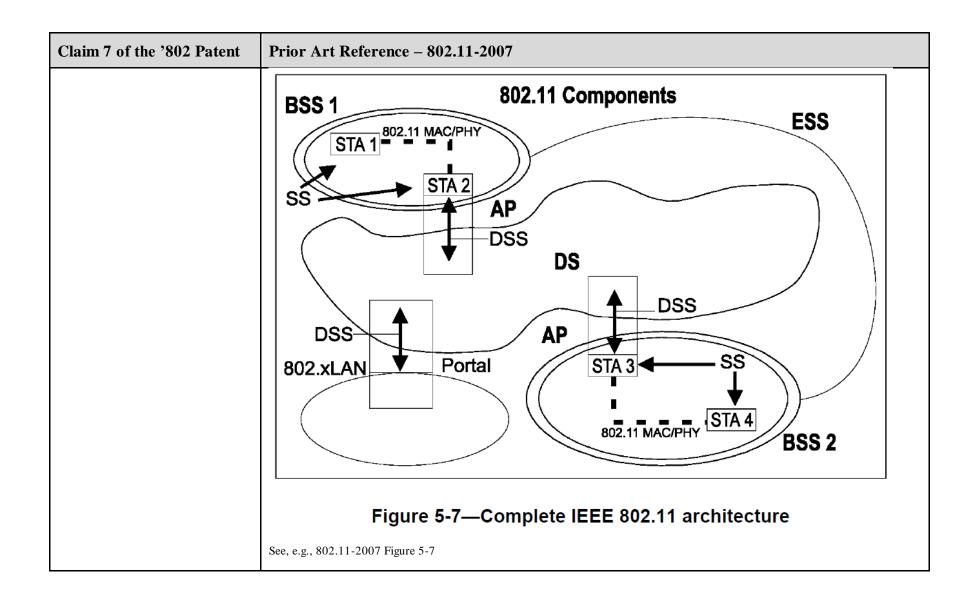
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	See, e.g., 802.11-2007 § 17.3.5.9

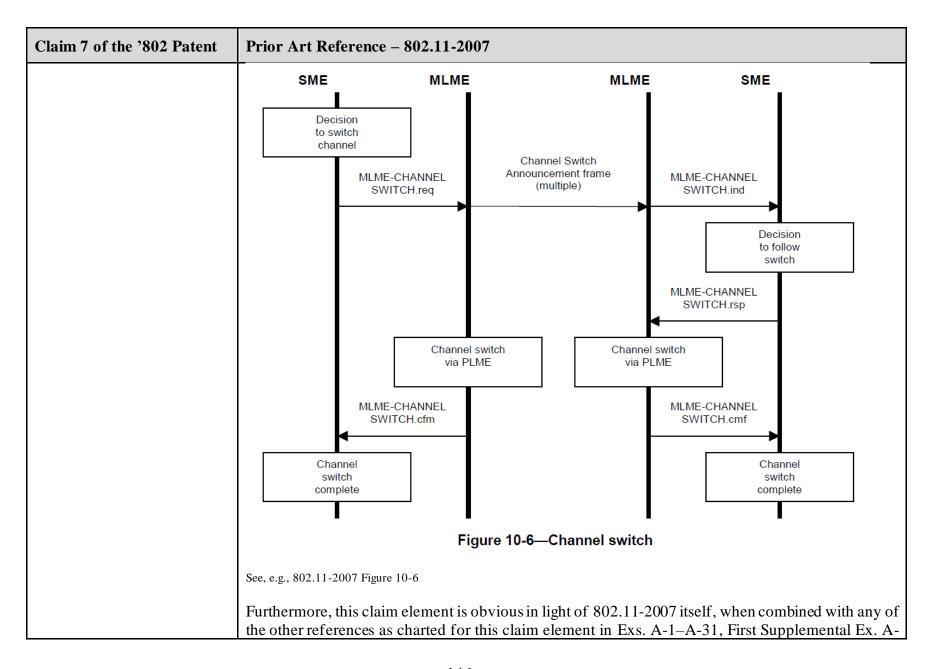


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

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	I.2.2 Transı	ansmit power levels						
		The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.						
	Table I.4—Transmit power level by regulatory domain							
		Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)		Europe (EIRP)			
		5.15-5.25	40 (2.5 mW/MHz)		200 mW			
		5.25-5.35	200 (12.5 mW/MHz)		200 mW			
		5.470-5.725	_		1 W			
		5.725-5.825	800 (50 mW/MHz)		_			
	Та	ble I.5—U.S. public sa	fety transmit po	ower levels by	regulatory domain	1		
		Frequency band (GHz)		. public safety (m				
		(GHz)	U.S 20 MHz channels	10 MHz channels	5 MHz channels			
			20 MHz	10 MHz	5 MHz			

Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative
	to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example) -28 dBr (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 7 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
[8.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.
[8.2] wherein the first information and the second information are from the same data stream.	802.11-2007 discloses "wherein the first information and the second information are from the same data stream." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only)
	DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,

aSIFSTime, aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Name	Туре	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receiv to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifler off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the firs chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.Indication (IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTIme. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10°)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets)/10°) + (8 × PSDUoctets)/ data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N)/10°) + (8 × N)/data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for

cod c) C the bits d) A zero strii e) I XO f) R retu deta g) E son "co h) I "int to 1 i) D gro Ref j) D asso and 8 to inso witt k) H sub l) F Fou for app m) RA' n) U of t An	spending a GI as described subsequently for data transmission with BPSK-OFDM modulated at ting rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded is per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit imig constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and DR it with the extended string of data bits. Refer to 17.3.5.4 for details. Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits urn the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for ails. Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) me of the encoder output string (chosen according to "puncturing pattern") to reach the desired ding rate. "Refer to 17.3.5.5 for details. Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an terleaving" (croordering) of the bits according to a rule corresponding to the desired RATE. Refer 17.3.5.6 for details. Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit ups, convert the bit group into a complex number according to the modulation encoding tables. For to 17.3.5.7 for details. Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit ups, convert the bit group into a complex number according to the modulation encoding tables. For to 20, and 22 to 26. The subcarriers are inserted as pilots into positions —21, —7, and 21 are skipped and, subsequently, used for erting pilot subcarriers. The 0 subcarriers sasociated with center frequ

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007				
	17.3.2.3 Timing related parameters				
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP.				
	Table 17-4—Timing-related parameters				
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	N _{SD} : Number of data subcarriers	48	48	48	
	N _{SP} : Number of pilot subcarriers	4	4	4	
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 $(N_{SD} + N_{SP})$	
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)	
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs (1/ Δ_F)	
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$	
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 $\mu s (T_{GI} + T_{FFT})$	
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)	
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)	
	T_{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 $\mu s (T_{GI} + T_{FFT})$	

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007					
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)		
	T_{SHORT} : Short training sequence duration	8 µs $(10 \times T_{FFT}/4)$	16 $\mu s (10 \times T_{FFT}/4)$	32 μs (10 × T _{FFT} /4)		
	T _{LONG} : Long training sequence duration	8 μ s ($T_{GIZ} + 2 \times T_{FFT}$)	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)		

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(i)} = Re\{r\langle t\rangle \exp(j2\pi f_c t)\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ m ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GID}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 8 of the '802 Patent	tent Prior Art Reference – 802.11-2007			
	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \end{cases} $ $\sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ (17-4)			
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.			
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}			
	$T = T_{GI2} + 2T_{FFT}$ T_{GUARD} $= T_{GI2}$ T_{FFT} T_{FFT} T_{TR} T_{TR} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for			
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)			

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007		
	17.3.2.5 Discrete time implementation considerations		
	The following descriptions of the discrete time implementation are informational.		
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes		

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007				
	17.3.3 PLCP preamble (SYNC)				
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.				
	$8 + 8 = 16 \mu\text{s}$ $10 \times 0.8 = 8 \mu\text{s}$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \mu\text{s}$ $0.8 + 3.2 = 4.0 \mu\text{s}$ $0.8 + 3.2 = 4.0 \mu\text{s}$ $0.8 + 3.2 = 4.0 \mu\text{s}$ $0.1 \text{GI} \text{Data 1}$ 0.1Data 2				
	Signal Detect, Coarse Freq. Channel and Fine Frequency RATE SERVICE + DATA DATA AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize				
	Figure 17-4—OFDM training structure				
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.				

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G.12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007				
	17.3.5.7 Subcarrier modulation mapping				
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).				
	$d = (I + jQ) \times K_{MOD}$			(17-20)	
	that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.				
	Table	17-6—Modulation-depend	dent normalization facto	r K _{MOD}	
		Modulation	K_{MOD}		
		BPSK	1		
	QPSK 1/√2				
		10.001			
		16-QAM	1/√10		

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{cases} N_{SD}^{-1} \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k)\Delta_{F}(t-T_{GI})) \\ N_{ST}^{/2} \\ + p_{n+1} \sum_{k=-N_{ST}^{/2}} P_{k} \exp(j2\pi k\Delta_{F}(t-T_{GI})) \\ k = -N_{ST}^{/2} \end{cases}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

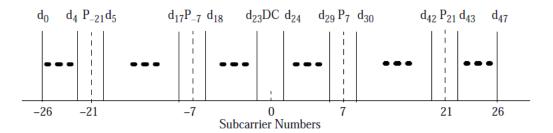


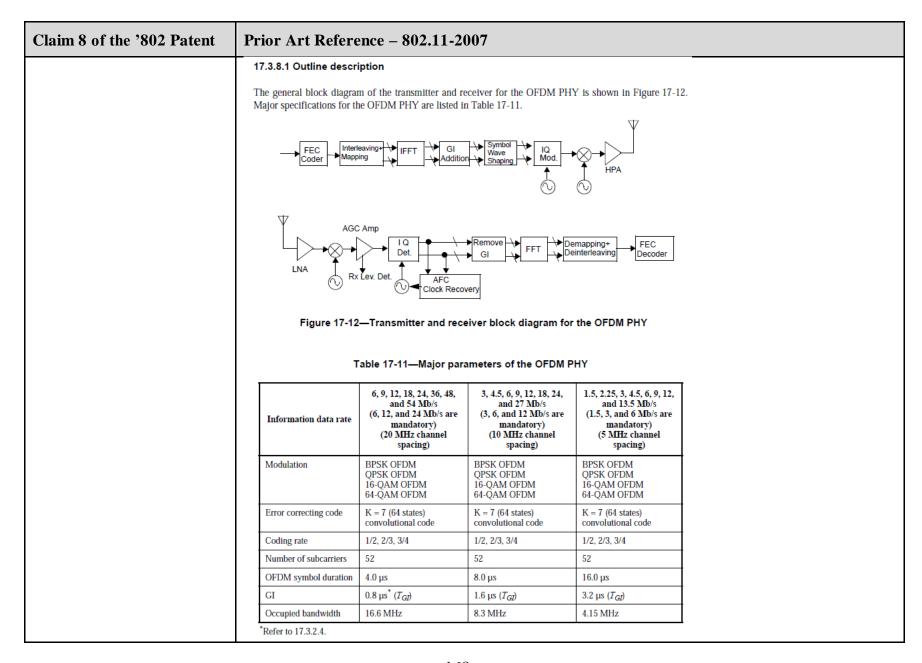
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
 (17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

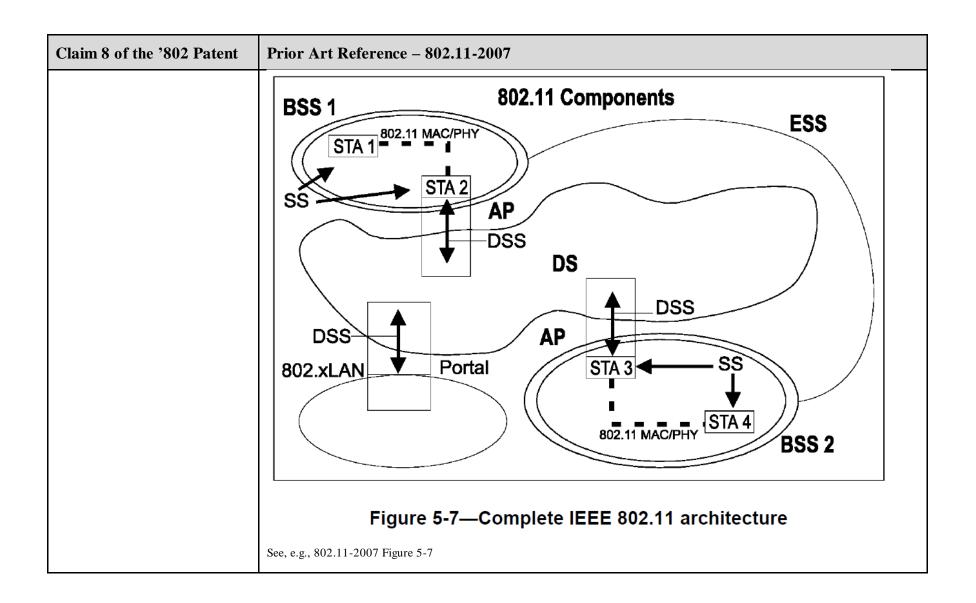
Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007	
	See, e.g., 802.11-2007 § 17.3.5.9	

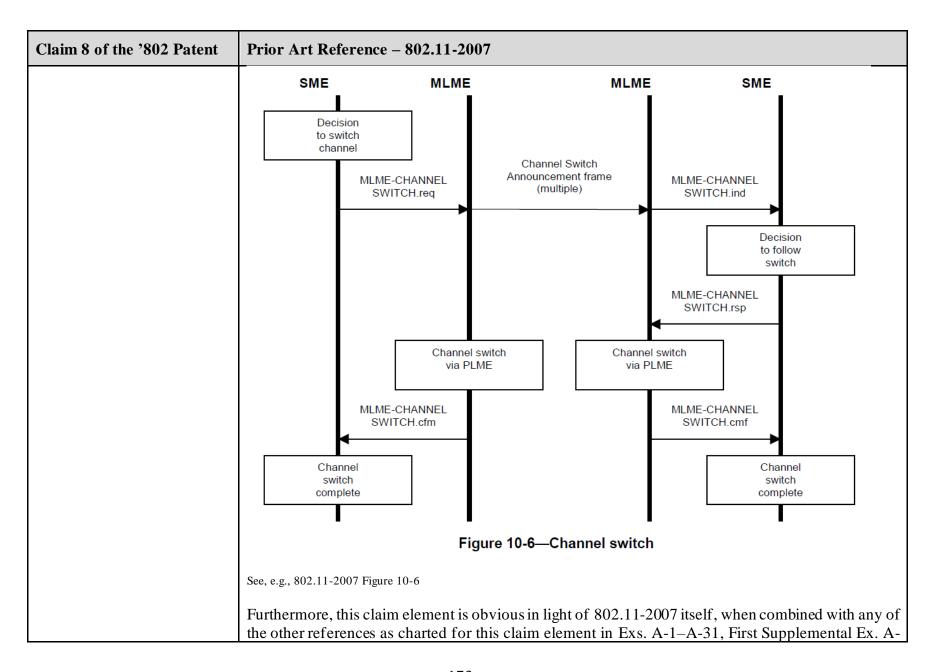


Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007 I.2.2 Transmit power levels					
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.					
		Table I.4—Transmit power level by regulatory domain United States Frequency band (Maximum output power with Europe (GHz) up to 6 dBi antenna gain) (EIRP) (mW)				
		5.15–5.25 40 (2.5 mW/MHz)		200 mW		
		5.25–5.35	200 (12.5 n	nW/MHz)	200 mW	
		5.470-5.725	_	-	1 W	
		5.725–5.825 800 (50 mW/MHz)		_		
	Tabl	e I.5—U.S. public sa	fety transmit po	ower levels by	regulatory domain	
	[Frequency band (GHz)		. public safety (m	-	
		Frequency band (GHz)	U.S 20 MHz channels	. public safety (m 10 MHz channels	W) 5 MHz channels	
			20 MHz	10 MHz	5 MHz	

Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example) -40 dBr -40 dBr
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 8 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007			
[9.1] The method of claim 1	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.			
[9.2] wherein first information and second information comprise a plurality of OFDM symbols, wherein a first symbol is transmitted during a first time slot across the first frequency range and a second symbol is transmitted during the first time slot across the second frequency range, and wherein a third symbol is transmitted during a second time slot across the first frequency range and a fourth symbol is transmitted during the second time slot across a second frequency range.	802.11-2007 discloses all the elements of claim 1 for all the reasons provided above.			

Claim 9 of the '802 Patent	Patent Prior Art Reference – 802.11-2007		
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas		
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.		
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.		
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.		
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.		
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3		
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This		

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007		
	communicate with other STAs present in the BSA.		
	See, e.g., 802.11-2007 § 5.2		
	5.2.3 Distribution system (DS) concepts		
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.		
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.		
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.		
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.		
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.		
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.		
	See, e.g., 802.11-2007 § 5.2.3		
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.		
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution		
	d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.		

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007		
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.		
	See, e.g., 802.11-2007 § 5.3.2		
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.		
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.		
	See, e.g., 802.11-2007 § 5.4.4.1		
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.		
	See, e.g., 802.11-2007 § 7.3.2.20		
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).		
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.		

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007	
	See, e.g., 802.11-2007 § 10.3.11	

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

> aSlotTime, aSIFSTime, aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay, aRxTxSwitchTime,

aTxRampOnTime, aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin, aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrmraroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Name	Туре	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receiv to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifler off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-FXEND.indication primitive (for response after SIFS) or PHY-FCCA.Indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for

prop	
codi c) C the c bits d) A zero strin e) Ir XOI f) R retur deta g) E som "cod h) E "inte to 1' i) D grou Refe j) D asso and 8 to inse with k) F subo l) Fo Four form appl m) A RAT n) U of tt An i	pending a GI as described subsequently for data transmission with BPSK-OFDM modulated at ling rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded is per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with o bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit in geonstitutes the DATA part of the packet. Refer to 17.3.5.3 for details. Initiate the scrambler with a pseudor-random nonzero seed, generate a scrambling sequence, and Ri twith the extended string of data bits. Refer to 17.3.5.4 for details. Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits turn the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for tails. Broode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) ne of the encoder output string (chosen according to "puncturing pattern") to reach the desired ding rate." Refer to 17.3.5.5 for details. Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an terleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer (17.3.5.5 for details.) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit ups. convert the bit group into a complex number according to the modulation encoding tables. The complex number string into groups of 48 complex numbers. Each such group will be ociated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 the appendence of the proper subcarriers are inserted as pilots into positions = 21, -7, 7, and 21 are skipped and, subsequently, used for ertiring

Claim 9 of the '802 Patent	Prior Art Reference – 802.1	1-2007		
	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N_{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 $(N_{SD} + N_{SP})$
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GIZ} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T _{SYM} : Symbol interval	4 μs $(T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 $\mu s (T_{GI} + T_{FFT})$

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)
	T_{LONG} : Long training sequence duration	8 µs $(T_{GI2} + 2 \times T_{FFT})$	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)^{(i)}} = Re\{r\langle t\rangle \exp(j2\pi f_c t)\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	$8 + 8 = 16 \mu\text{s}$ $10 \times 0.8 = 8 \mu\text{s}$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \mu\text{s}$ $t_1 \ t_2 \ t_3 \ t_4 \ t_5 \ t_6 \ t_7 \ t_8 \ t_9 \ t_{10} \ \text{GI2} \ \text{I}$ $T_1 \ T_2 \ \text{GI SIGNAL GI Data 1}$
	Signal Detect, Coarse Freq. Channel and Fine Frequency RATE SERVICE + DATA DATA Offset Estimation Offset Estimation Timing Synchronize Signal Detect, Coarse Freq. Channel and Fine Frequency RATE SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

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A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{eff}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			ded into groups of N_{BPSC} K, 16-QAM, or 64-QAM I constellation mappings, The output values, d, are
				(17-20)
	The normalization factor, K_{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 17-6—Modulation-dependent normalization factor K _{MOD}			r K _{MOD}
		Modulation	K_{MOD}	
		BPSK	1	
		QPSK	1/√2	
		16-QAM	1/√10	
		64-QAM	1/√42	
	See, e.g., 802.11-2007 § 17.3.5	5.7		

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

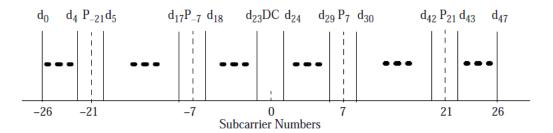


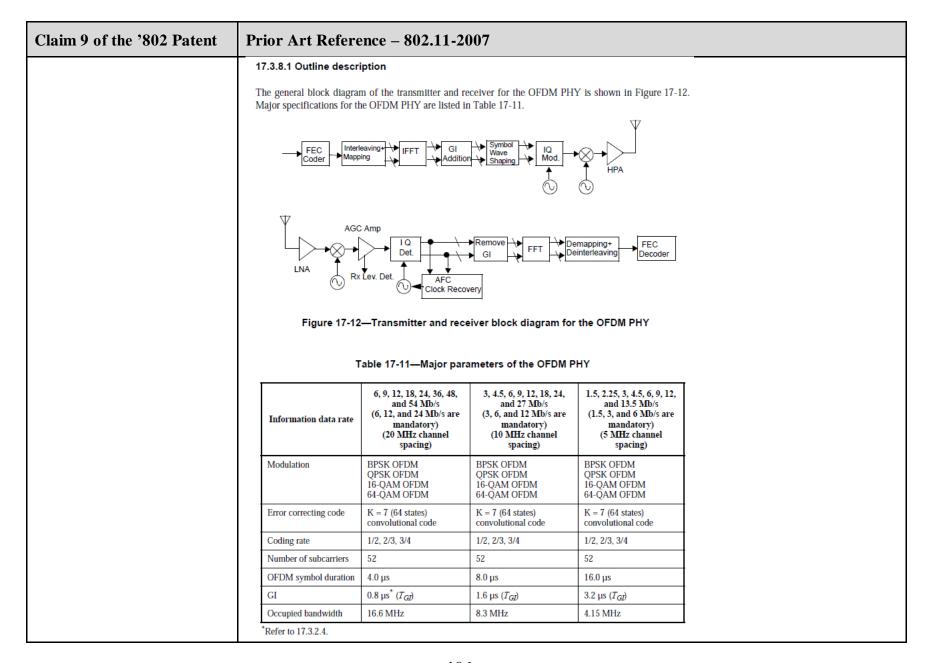
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

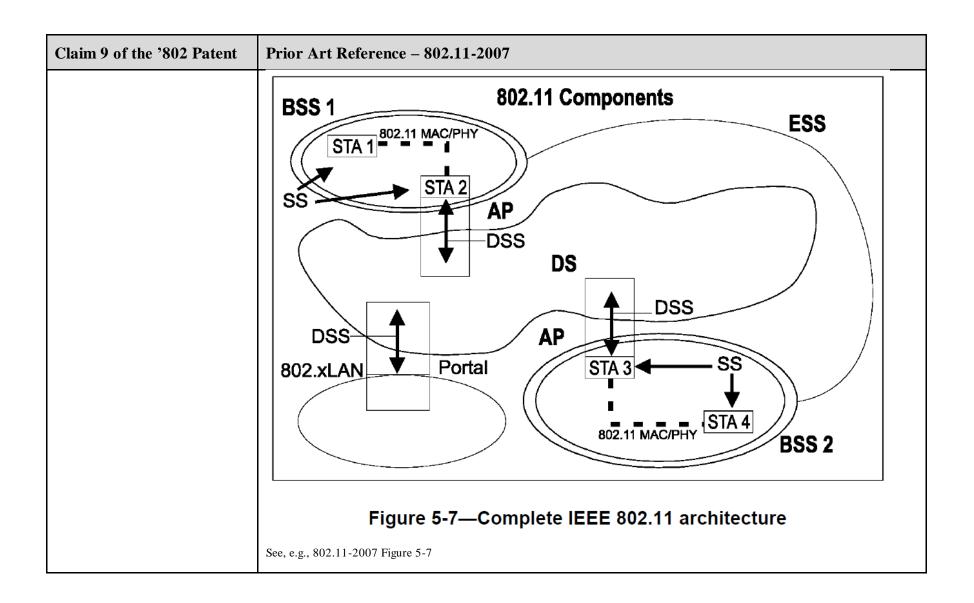
Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007	
	See, e.g., 802.11-2007 § 17.3.5.9	

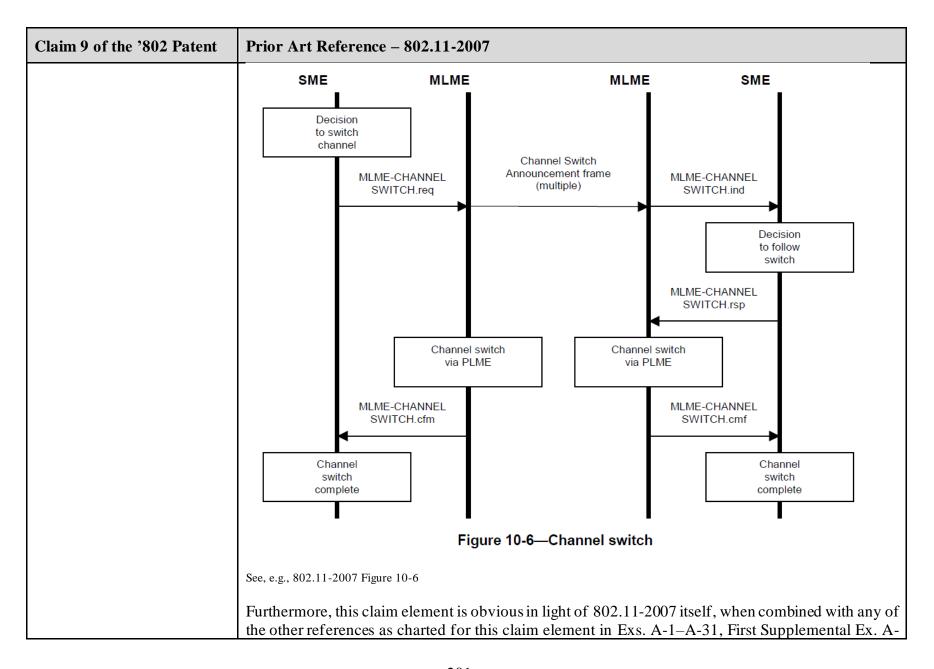


Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007					
	I.2.2 Transmit po	I.2.2 Transmit power levels				
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5. Table I.4—Transmit power level by regulatory domain				able I.4. The is shown in	
		ency band GHz)	United (Maximum out) up to 6 dBi at (m)	put power with ntenna gain)	Europe (EIRP)	
	5.1	5-5.25	40 (2.5 m	W/MHz)	200 mW	1
	5.2	5.25–5.35 200 (12.5 mW/MHz)		200 mW	1	
	5.47	5.470–5.725 —		1 W		
	5.72	5-5.825	800 (50 m	W/MHz)	_	
	Table I.5-	Table I.5—U.S. public safety transmit power levels by regulatory dome U.S. public safety (mW) Frequency band			regulatory domair	1
	Fre	equency band - (GHz)				
	Fre		U.S 20 MHz channels	5. public safety (m 10 MHz channels	5 MHz channels	
			20 MHz	10 MHz	5 MHz	

Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative
	to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example) -40 dBr
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 9 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
[10.1] A method of transmitting information in a wireless communication channel comprising:	To the extent the preamble is limiting, 802.11-2007 discloses "A method of transmitting information in a wireless communication channel comprising." See, e.g.:

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	$8 + 8 = 16 \mu\text{s}$ $10 \times 0.8 = 8 \mu\text{s}$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \mu\text{s}$ $0.8 + 3.2 = 4.0 \mu\text{s}$
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

(17-8)

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.2] receiving a first digital signal comprising first data to be transmitted;	802.11-2007 discloses "receiving a first digital signal comprising first data to be transmitted." See, e.g.:
be transmitted,	1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.
	See, e.g., 802.11-2007 § 1.1
	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every

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	other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks

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	this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC

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	Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime, aPHY-RX-START-Delay, aRxTxTurnaroundTime, aTxPLCPDelay, aRxPLCPDelay, aRxTxSwitchTime, aTxRampOnTime, aTxRampOffTime, aTxRFDelay, aRxRFDelay, aAirPropagationTime, aMACProcessingDelay, aPreambleLength, aPLCPHeaderLength, aMPDUDurationFactor,

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

aMPDUMaxLength, aCWmin, aCWmax

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: atxPLCPDelay + arxTxSwitchTime + atxRampOnTime + atxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Name Type Description	Prior Art Refe	rence –	802.11-2007
aTXRampOnTime integer The maximum time (in microseconds) that the PMD takes to turn the Transmilt on. aTXRTPDelay integer The nominal time (in microseconds) that the PMD takes to turn the Transmilt Power Amplifier off. The nominal time (in microseconds) between the Issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air microsecond in the air micro	Name	Туре	Description
aTXRampOffTime Integer The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off. The nominal time (in microseconds) between the issuance of a PMD. DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is denote to be 17.9 ymbol period prior to the center of the symbol for DATA. Prequest to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol for FH, or 172 chip period prior to the center of the first chip of the symbol for FH, or 172 chip period prior to the center of the first chip of the symbol for FH, or 172 chip period after the center of the symbol for DS, or 172 slot time after the center of the symbol for DS, or 172 slot time after the center of the corresponding slot for IR. The nominal time (in microseconds) between the end of a symbol at the air interface to the Issuance of a PMD. DATA. Indicate to the PLCP. The end of a symbol as defined to be 172 symbol period after the center of the corresponding slot for IR. The nominal time (in microseconds) between the end of a symbol at the air interface to the Issuance of a PMD. DATA. Indicate to the PLCP. The end of a symbol as defined to be 172 symbol period and the symbol for PL, or 172 chip period after the center of the Lorenton of the Symbol for DS, or 172 slot time after the center of the corresponding slot for IR. The maximum time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized. The maximum time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized. The maximum time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized. The maximum time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized. The maximum time (in micr	aRxTxSwitchTime	integer	
attribute of the state of the corresponding symbol at the aft interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for DH, or 1/2 chip period prior to the center of the symbol for DH, or 1/2 chip period prior to the center of the symbol for DH, or 1/2 chip period prior to the center of the symbol for DH, or 1/2 chip period prior to the center of the symbol for DH, or 1/2 chip period prior to the center of the symbol for DH, or 1/2 chip period after the center of the symbol for DH, or 1/2 chip period after the center of the symbol for DH, or 1/2 chip period after the center of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR. aAltPropagationTime integer after the center of the corresponding slot for IR. aMACProcessingDelay integer after the center of the corresponding slot for IR. The maximum time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized. The propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized. The propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized. The propagation time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-EXEA. That is a slot synchronized and synchronized as a PHY-START. The propagation time (in microseconds) and the propagation of the modulated propagation time (in microseconds) and the propagation of the synchronized and the time state of the single synchronized and START. The corresponding of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value. The current PHY's PLC Pheader length (in microseconds). If the actual value of the length of the modulated preamble is not	aTxRampOnTime	integer	
aTXRFDelay linteger The nominal time (in microseconds) between the issuance of a PMD. DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for EH. or 1/2 chips of the cymbol for DS, or 1/2 slot time prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the air interface to the Issuance of a PMD. DATA indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for EH, or 1/2 chip period after the center of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR. aAirPropagationTime integer Integer Twice time in microseconds available of a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronzed. The maximum time (in microseconds) available for the MAC is Data and the IFS and slot timing the for the MAC is Data and the IFS and slot timing the for the MAC is Data and the IFS and slot timing is described in 9.2.10 and dilustrated in Figure 9-12. aPreambleLength Integer The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value Is rounded up to the next higher value. aPDUDurationFactor Integer The overhead added by the PHY to the MPDU as it is transmitted through the WAC expressed as a scaling factor applied to the number of bits in the MPDU. The value of aAMPDUDurationFactor is generated by the following equation: Turucate (PPDUDurationFactor is a PPDUD tower the air is generated by the following equation: Turucate (PPDUDurationFactor is a PPDUD tower the air is generated by the following equation: Turucate (PPDUDurationFactor is a PPDUD tower the air is generated by the following equation: Turucate (PPDUDurationFactor is the PPDUDuration fa	aTxRampOffTime	integer	
Interface to the Issuance of a PMD_DATA_indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the teast chip of the symbol for DS, or 1/2 slot time after the center of the center o	aTxRFDelay	Integer	PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the
distance between the most distant allowable STAs that are slot synchronized. The maximum time (in microseconds) available for the MAC to Issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA. Indication (IDLE) primitive (for response after SIFS) or PHY-CCA. Indication (IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific parameter because of the suse, along with other PHY-s	aRxRFDelay	integer	Interface to the Issuance of a PMD_DATA indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2
TXSTART:request primitive pursuant to a PHY-RXEND.indication primitive for response at a ray slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12. aPreambleLength	aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
length of the modulated preamble is not an integral number of microseconds, the value Is rounded up to the next higher value. The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value Is rounded up to the next higher value. Integer Integer Integer The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[(PPDUbits/PSDUbits)-1) × 10*]). The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength, + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10*9) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10*) + (8 × N) / (4 × N) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the preamble PLCP header. aMPDUMaxLength Integer The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU). aCWmin Integer The minimum size of the CW, in units of aSlotTime.	aMACProcessingDelay	integer	TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.Indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and
the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value. The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncatei ([PPDUblits/PSDUbits)-1) × 10 ⁹]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer us: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10 ⁹) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in us) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10 ⁹) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header. The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU). aCWmin integer The minimum size of the CW, in units of aSlotTime.	aPreambleLength	integer	length of the modulated preamble is not an integral number of microseconds, the
WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncatel ((PPDUblits/PSDUblts)-1) × 10*)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer μs:	aPLCPHeaderLength	integer	the length of the modulated header is not an integral number of microseconds,
protocol data unit (PPDU). aCWmin integer The minimum size of the CW, in units of aSlotTime.	aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[(IPPDUbits/PSDUbits)—1) × 10 ³⁰]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10 ³⁰) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10 ³⁰) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the
aCWmin integer The minimum size of the CW, in units of aSlotTime.	aMPDUMaxLength	integer	
			The minimum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. b) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.5 for details. b) Divide the complex number string into groups of 48 complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers are numbered —26 to —22, —20 to —8, —6 to —1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –27 (-7, 7,
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters				
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	N_{SD} : Number of data subcarriers	48	48	48	
	N _{SP} : Number of pilot subcarriers	4	4	4	
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)	
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$	
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$	
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)	
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)	
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)	
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μ s (10 × T_{FFT} /4)
	T_{LONG} : Long training sequence duration	8 μ s ($T_{GI2} + 2 \times T_{FFT}$)	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(i)} = Re\{r(t)\exp(j2\pi f_c t)\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} (a)
	$T = T_{GIZ} + 2T_{FFT}$ $T_{GUARD} = T_{GIZ}$ T_{FFT} T_{FFT} T_{TT} T_{TT} T_{TT} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007		
	17.3.3 PLCP preamble (SYNC)		
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.		
	$8+8=16\mu\text{s}$ $10\times0.8=8\mu\text{s}$ $2\times0.8+2\times3.2=8.0\mu\text{s}$ $t_1t_2t_3t_4t_5t_6t_7t_8t_9t_{10}\text{GI2}$ $Coarse \text{Freq.}$ $Channel \text{and}\text{Fine}\text{Frequency}$ $RATE$ $Channel \text{and}\text{Fine}\text{Frequency}$ $RATE$ $SERVICE + DATA DATA$		
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize		
	Figure 17-4—OFDM training structure		
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.		

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD} $ (17)			
	that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	same average power for normalization factor can be	all mappings. In practica	al implementations, an ap	proximate value of the
	same average power for normalization factor can be described in 17.3.9.6.	all mappings. In practica	al implementations, an ap conforms with the modulation	proximate value of the on accuracy requirements
	same average power for normalization factor can be described in 17.3.9.6.	e all mappings. In practica e used, as long as the device	al implementations, an ap conforms with the modulation	proximate value of the on accuracy requirements
	same average power for normalization factor can be described in 17.3.9.6.	all mappings. In practicate used, as long as the device 7-6—Modulation-depend	al implementations, an appointmentations an appointmentation and appointmentation for the modulation factor and the modula	proximate value of the on accuracy requirements
	same average power for normalization factor can be described in 17.3.9.6.	all mappings. In practicate used, as long as the device 7-6—Modulation-dependent Modulation	al implementations, an approximation $\mathbf{k}_{\mathbf{MOD}}$	proximate value of the on accuracy requirements
	same average power for normalization factor can be described in 17.3.9.6.	7-6—Modulation-dependent BPSK	al implementations, an appropriate conforms with the modulation dent normalization factor $\mathbf{K}_{\mathbf{MOD}}$	proximate value of the on accuracy requirements

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA} n(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

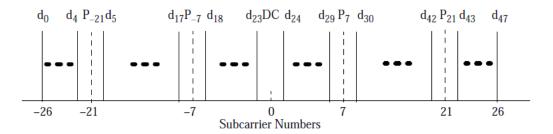


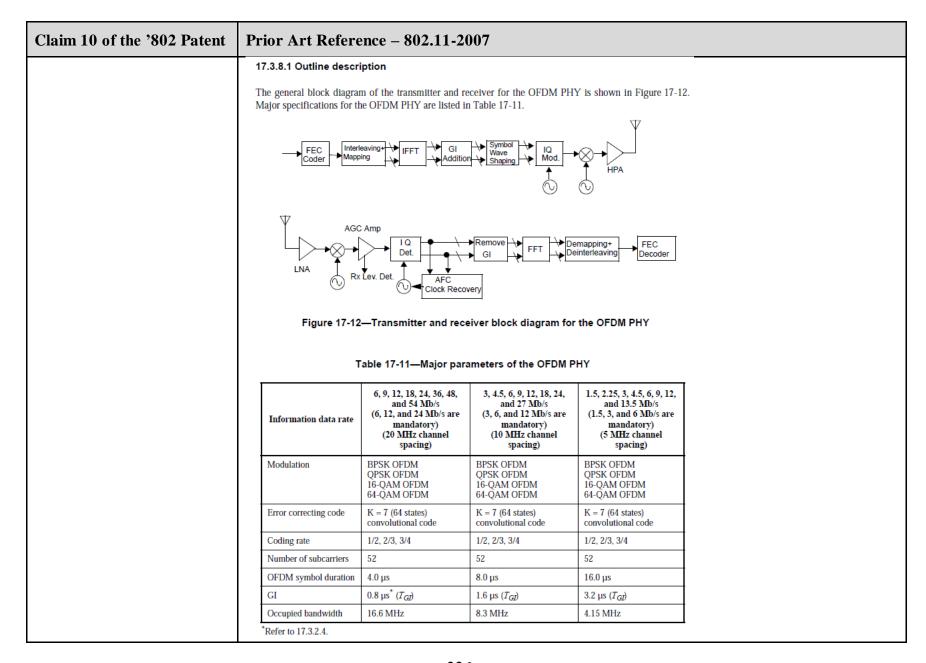
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

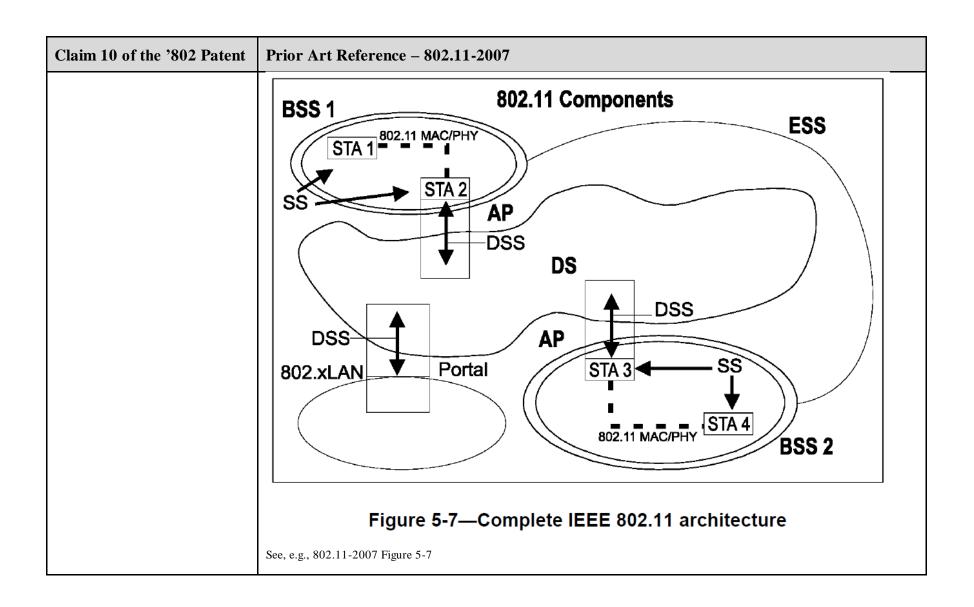
Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

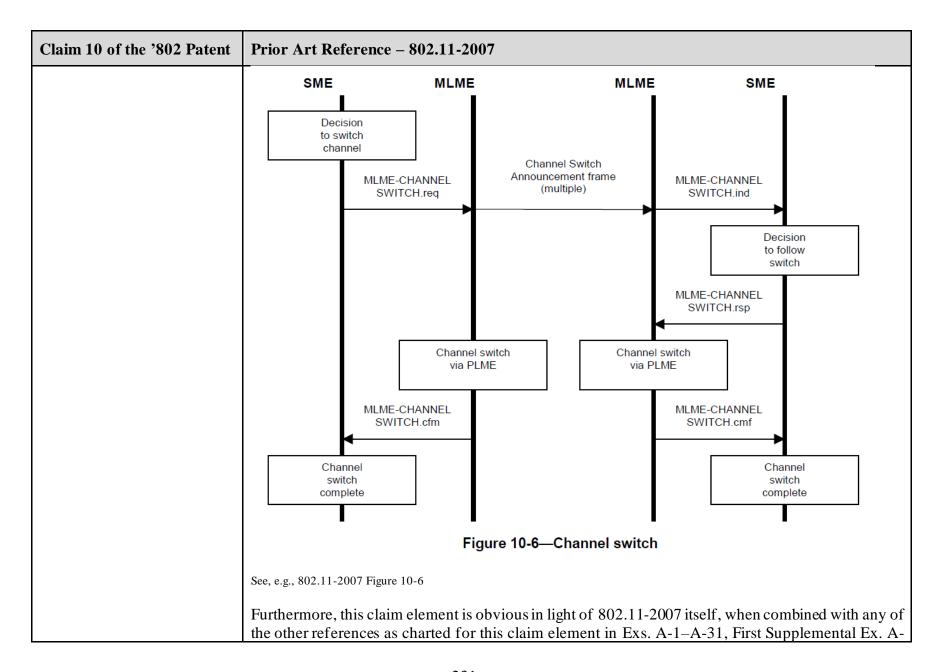


Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A comp liant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007					
	I.2.2 Transmit power levels					
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5. Table I.4—Transmit power level by regulatory domain					
		Frequency band (Maximum output power with Europe (GHz) up to 6 dBi antenna gain) (EIRP)				
	5.15-	5.15–5.25 40 (2.5 mW/MHz)		200 mW		
	5.25-	5.25–5.35 200 (12.5 mW/MHz)		200 mW	1	
	5.470-	5.470–5.725 —		1 W		
	5.725-	5.825	25 800 (50 mW/MHz)		_	
				,	regulatory doma	in
	Frequ	oney hand	U.S	S. public safety (mV	W)	
		nency band (GHz)	U.S 20 MHz channels	S. public safety (m 10 MHz channels	5 MHz channels	
			20 MHz	10 MHz	5 MHz	

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007		
	I.2.3 Transmit spectrum mask		
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.		
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)		
	Typical Signal Spectrum (an example)		
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)		
	Figure I.1—Transmit spectrum mask		
	See, e.g., 802.11-2007 § I.2.3		





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	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.3] receiving a second digital signal comprising second data to be transmitted;	802.11-2007 discloses "receiving a second digital signal comprising second data to be transmitted." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.
	See, e.g., 802.11-2007 § 1.1
	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

	-	
Name aRxTxSwitchTime	Type	Description The nominal time (in microseconds) that the PMD takes to switch from Receive
aTxRampOnTime	Integer	to Transmit. The maximum time (in microseconds) that the PMD takes to turn the
•		Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	Integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of ooded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. b) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.5 for details. b) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers and the com
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μ s ($T_{SHORT} + T_{LONG}$)
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 μ s ($T_{GI} + T_{FFT}$)	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (T _{FFT} /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)
	T_{LONG} : Long training sequence duration	8 μ s (T_{GI2} + 2 \times T_{FFT})	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(\phi)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GIZ}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007		
	17.3.2.5 Discrete time implementation considerations		
	The following descriptions of the discrete time implementation are informational.		
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes		

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	$8 + 8 = 16 \mu\text{s}$ $10 \times 0.8 = 8 \mu\text{s}$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \mu\text{s}$ $10 \times 0.8 + 3.2 = 4.0 \mu\text{s}$ $10 \times 0.8 + 3.2 = 4.$
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD} $ (17-20)			
	The normalization factor, K _{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 17-6—Modulation-dependent normalization factor K _{MOD}			
		Modulation	K_{MOD}	
		BPSK	1	
		QPSK	1/√2	
		16-QAM	1/√10	
		64-QAM	1/√42	
	See, e.g., 802.11-2007 § 17.3.5	5.7		

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	17.3.5.8 Pilot subcarriers		
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.		
	See, e.g., 802.11-2007 § 17.3.5.8		

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

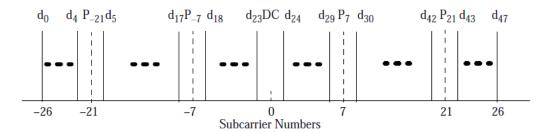


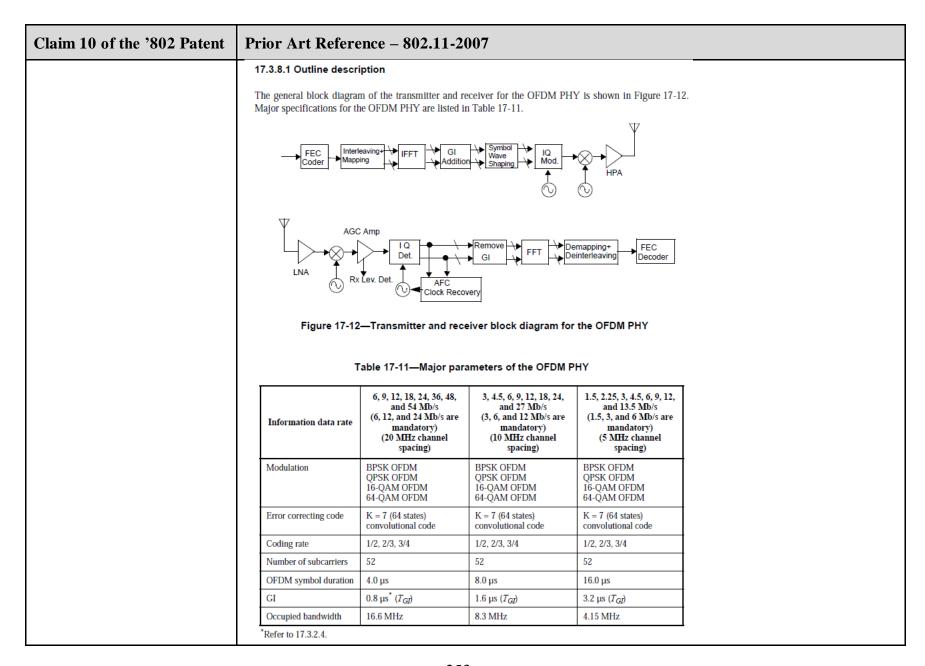
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

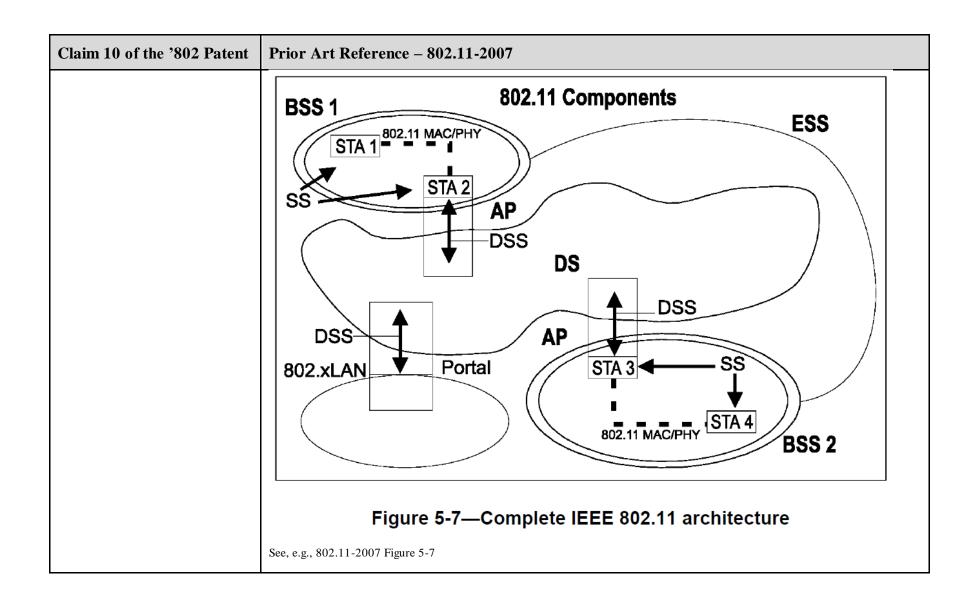
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	See, e.g., 802.11-2007 § 17.3.5.9

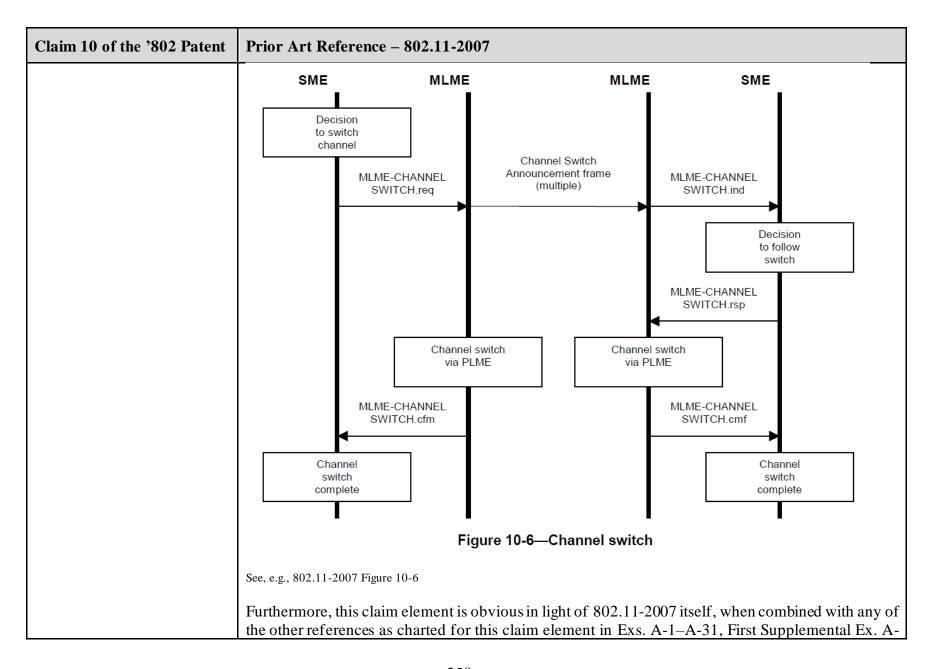


Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007				
	See, e.g., 802.11-2007 § 17.3.8.1				
	17.3.8.3.1 Operating frequency range				
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.				
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.				
	See, e.g., 802.11-2007 § 17.3.8.3.1				
	17.3.9.1 Transmit power levels				
	The maximum allowable transmit power by regulatory domain is defined in Annex I.				
	See, e.g., 802.11-2007 § 17.3.9.1				
	17.3.9.6.2 Transmitter spectral flatness				
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.				
	See, e.g., 802.11-2007 § 17.3.9.6.2				

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	I.2.2 Transmit power levels				
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown Table I.5.				
	Table	I.4—Transmit power lev	vel by regulatory	y domain	
	Frequency bar (GHz)	nd (Maximum ou up to 6 dBi :	d States tput power with antenna gain) nW)	Europe (EIRP)	
	5.15–5.25	40 (2.5 r	mW/MHz)	200 mW	
	5.25-5.35	200 (12.5	mW/MHz)	200 mW	
	5.470-5.725	-	_	1 W	
	5.725-5.825	800 (50 t	mW/MHz)	_	
		•			
	Frequency	band	.S. public safety (m	w)	
		band U.			
	Frequency	band) 20 MHz channels	.S. public safety (m\	W) 5 MHz	

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	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





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[10.4] converting the first	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "converting the first digital signal into a first analog signal using a first digital-
digital signal into a first analog signal using a first digital-to-analog converter,	to-analog converter, the first analog signal carrying the first data across a first frequency range." See, e.g.: 1.1 Scope
the first analog signal carrying the first data across a first frequency range;.	The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1
	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

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	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.			
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.			
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.			
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.			
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3			
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.			
	See, e.g., 802.11-2007 § 5.2			
	5.2.3 Distribution system (DS) concepts			
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.			
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.			

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	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

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	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1 7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Prior Art Refe	rence –	802.11-2007
Name	Туре	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoc
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction			
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.			
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.			
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.			
	See, e.g., 802.11-2007 § 17.1			
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:			
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the BLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for			
	TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of $R = 1/2$, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a			

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subscarrier (RDBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers are numb
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP.					
	Table 17-4—Timing-related parameters					
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)		
	N _{SD} : Number of data subcarriers	48	48	48		
	N_{SP} : Number of pilot subcarriers	4	4	4		
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})		
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)		
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$		
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$		
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)		
	T_{GI} : GI duration	0.8 μs (T _{FFT} /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)		
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)		
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)		

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)	
	T_{LONG} : Long training sequence duration	8 μ s (T_{GI2} + 2 \times T_{FFT})	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)	

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(\phi)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GIZ}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G.12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 10 of the '802 Patent	Prior Art Reference –	802.11-2007		
	17.3.5.7 Subcarrier mo	odulation mapping		
	RATE requested. The enc (1, 2, 4, or 6) bits and con- constellation points. The illustrated in Figure 17-10	nall be modulated by using BF oded and interleaved binary sometred into complex number conversion shall be performed, with the input bit, b ₀ , being the resulting (I+jQ) value	erial input data shall be divers representing BPSK, QPS ed according to Gray-coders the earliest in the stream.	ided into groups of <i>N_{BPSC}</i> K, 16-QAM, or 64-QAM d constellation mappings, The output values, d, are
	$d = (I + jQ) \times K_{MOD}$			(17-20)
	from SIGNAL to DATA, same average power for	can be different from the start as shown in Figure 17-1. The r all mappings. In practica be used, as long as the device	e purpose of the normalizati al implementations, an ap	on factor is to achieve the opproximate value of the
	Table 1	7-6—Modulation-depend	lent normalization facto	or K _{MOD}
		Modulation	K_{MOD}	
		BPSK	1	
		QPSK	1/√2	
		16-QAM	1/√10	
		64-QAM	1/√42	
	See, e.g., 802.11-2007 § 17.3.5	5.7		

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA} n(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

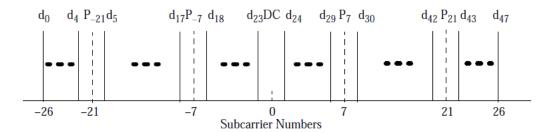


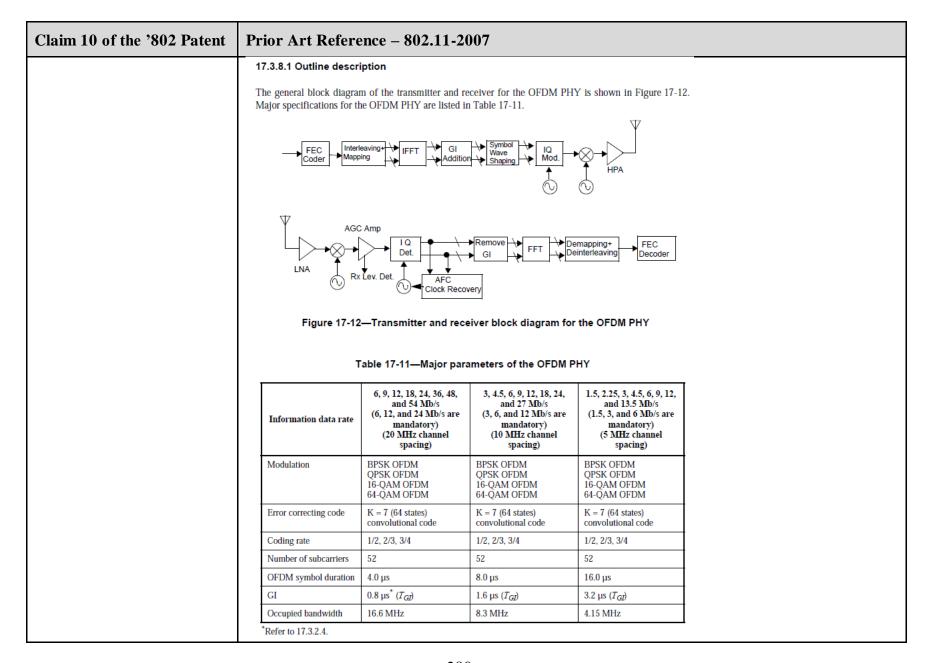
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

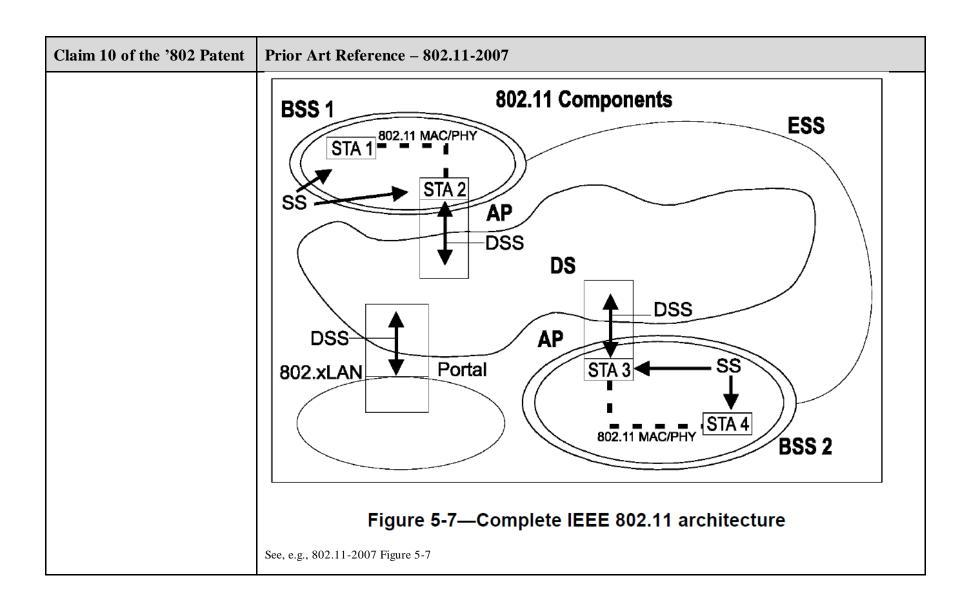
Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

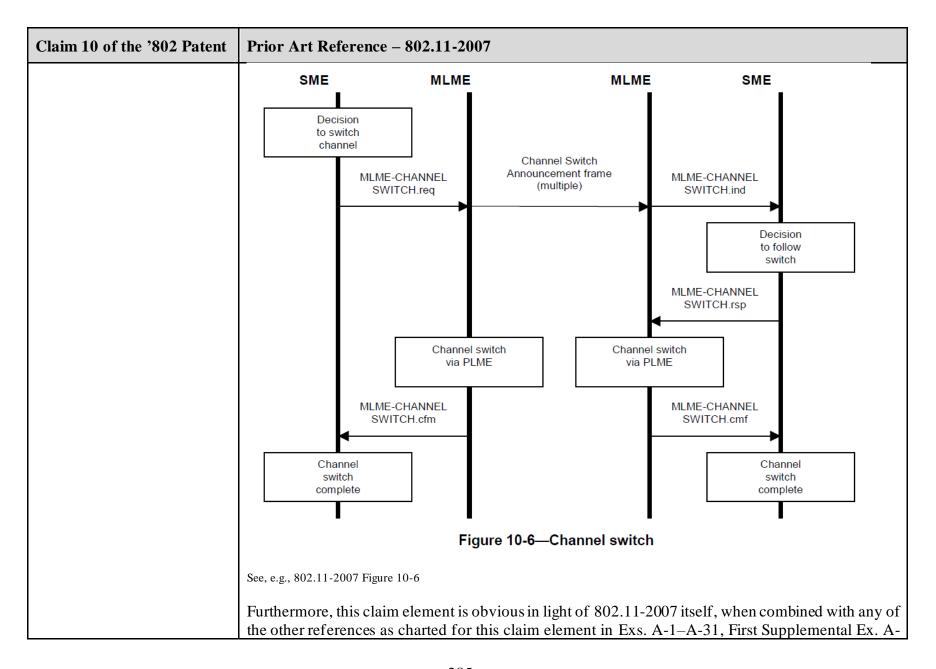


Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007						
	I.2.2 Transn	I.2.2 Transmit power levels The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is show Table I.5.					
	maximum allov						
		Table I.4—Transmit power level by regulatory domain					
		Frequency band (GHz)	United (Maximum out) up to 6 dBi at (m)	put power with ntenna gain)	Europe (EIRP)		
		5.15-5.25	40 (2.5 m	W/MHz)	200 mW		
		5.25-5.35	200 (12.5 r	nW/MHz)	200 mW		
		5.470-5.725	_	-	1 W		
		5.725-5.825	800 (50 m	W/MHz)	_		
	Tak	5.470-5.725	800 (50 m	- W/MHz)	1 W		
		Frequency band	U.S	5. public safety (mV	V)		
		Frequency band (GHz)	U.S 20 MHz channels	5. public safety (mV 10 MHz channels	5 MHz channels		
			20 MHz	10 MHz	5 MHz		

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall
	within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example) -28 dBr
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
[10.5] converting the second	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "converting the second digital signal into a second analog signal using a
digital signal into a second analog signal using a second digital-to-analog converter, the second analog signal	second digital-to-analog converter, the second analog signal carrying the second data across a second frequency range." See, e.g.: 1.1 Scope
carrying the second data across a second frequency range;	The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1
	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1 7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

a Tx PLCPD elay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

	-	
Name aRxTxSwitchTime	Type	Description The nominal time (in microseconds) that the PMD takes to switch from Receive
aTxRampOnTime	Integer	to Transmit. The maximum time (in microseconds) that the PMD takes to turn the
•		Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	Integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the
	TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of $R = 1/2$, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subscarrier (RDBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers are numb
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters			
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP.			
	Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μ s ($T_{SHORT} + T_{LONG}$)
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 μ s ($T_{GI} + T_{FFT}$)	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (T _{FFT} /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μs $(10 \times T_{FFT}/4)$	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)
	T _{LONG} : Long training sequence duration	8 µs $(T_{GI2} + 2 \times T_{FFT})$	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$
	See, e.g., 802.11-2007 § 17.3.2.3	-		

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(\phi)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GIZ}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} (a)
	$T = T_{GIZ} + 2T_{FFT}$ $T_{GUARD} = T_{GIZ}$ T_{FFT} T_{FFT} T_{TT} T_{TT} T_{TT} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

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A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G.12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD}$			(17-20)
	The normalization factor, K _{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 1	7-6—Modulation-depend	lent normalization facto	or K _{MOD}
		Modulation	K_{MOD}	
	BPSK 1			
	QPSK $1/\sqrt{2}$ 16-QAM $1/\sqrt{10}$ 64-QAM $1/\sqrt{42}$ See, e.g., $802.11\text{-}2007 \ \ 17.3.5.7$			

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	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{cases} N_{SD}^{-1} \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k)\Delta_{F}(t-T_{GI})) \\ N_{ST}^{/2} \\ + p_{n+1} \sum_{k=-N_{ST}^{/2}} P_{k} \exp(j2\pi k\Delta_{F}(t-T_{GI})) \\ k = -N_{ST}^{/2} \end{cases}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

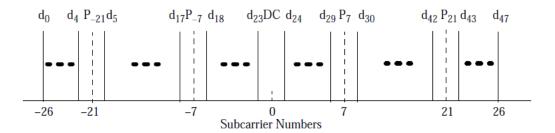


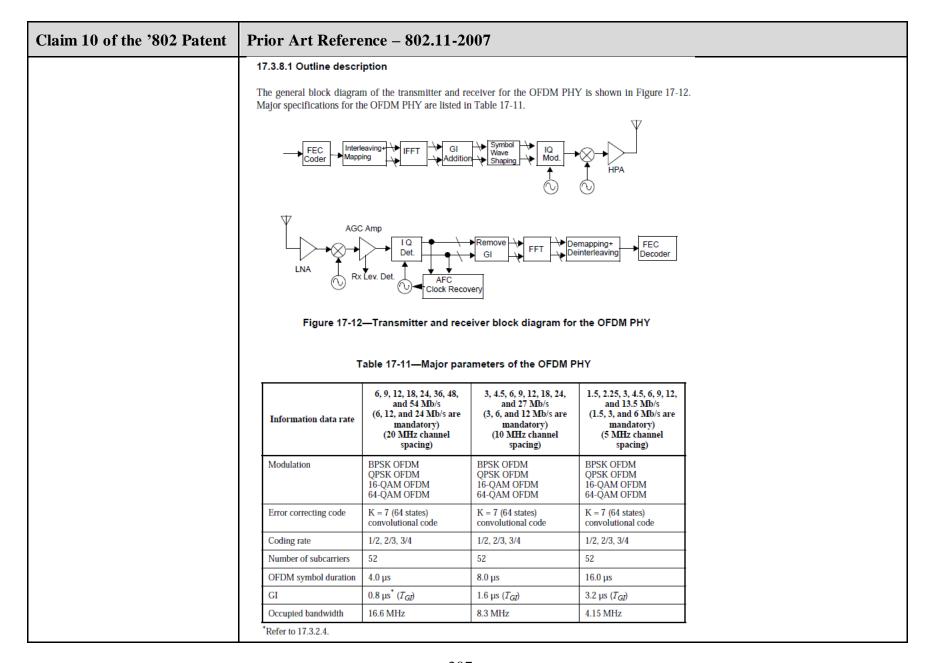
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

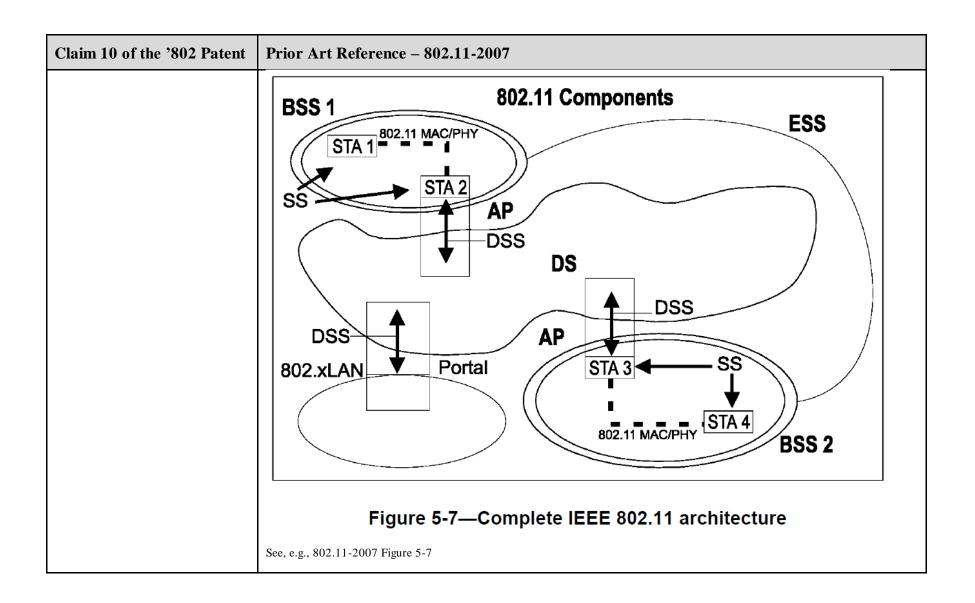
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	See, e.g., 802.11-2007 § 17.3.5.9	

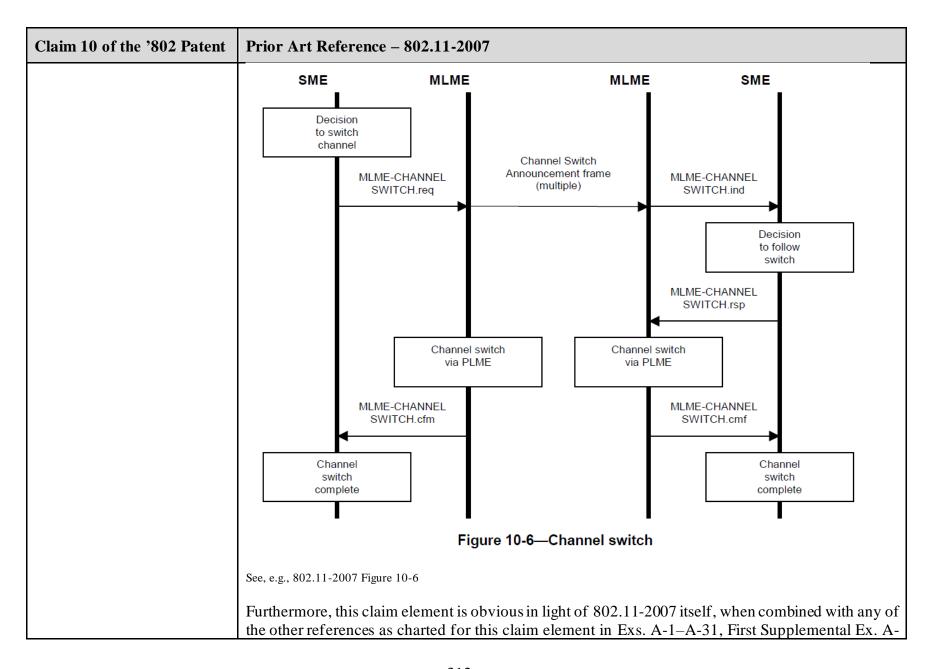


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

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	I.2.2 Transmit power levels The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5. Table I.4—Transmit power level by regulatory domain				
	Frequency ba (GHz)	and (Maximum up to 6 dI	ted States output power with Bi antenna gain) (mW)	Europe (EIRP)	
	5.15–5.25	40 (2.	5 mW/MHz)	200 mW	1
	5.25-5.35	200 (12	2.5 mW/MHz)	200 mW	
	5.470-5.72	5	_		
	5.725-5.82	5 800 (5	0 mW/MHz)	_	
	Table I.5—U.S.	public safety transmi	t power levels by	regulatory domair	1
	Frequenc	y band	U.S. public safety (m		
		y band	U.S. public safety (m 10 MHz channels	W) 5 MHz channels	
	Frequenc	y band z) 20 MHz channels	10 MHz	5 MHz	

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	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example) -40 dBr
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





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[10.6] up-converting the first analog signal to a first RF center frequency to produce a first up-converted analog signal, wherein the first up-converted analog signal comprises a first up-converted frequency range from the first RF center frequency minus one-half the first frequency range to the first RF center frequency plus one-half the first frequency range;	Prior Art Reference – 802.11-2007 Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "up-converting the first analog signal to a first RF center frequency to produce a first up-converted analog signal, wherein the first up-converted analog signal comprises a first up-converted frequency range from the first RF center frequency minus one-half the first frequency range to the first RF center frequency plus one-half the first frequency range." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs, in IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping

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	areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is

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	built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used

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	to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,

aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

a Tx Ramp On Time,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Туре	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Prior Art Refe	rence –	802.11-2007
Name	Туре	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	Integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIES) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. C) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.1 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers acc
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N _{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 × T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)
	T _{LONG} : Long training sequence duration	8 $\mu s (T_{GI2} + 2 \times T_{FFT})$	16 µs $(T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)^{(i)}} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{\rm ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GID}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$		
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.		
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} (a)		
	$T = T_{GIZ} + 2T_{FFT}$ $T_{GUARD} = T_{GIZ}$ T_{FFT} T_{FFT} T_{TT} T_{TT} T_{TT} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for		
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)		

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	17.3.2.5 Discrete time implementation considerations	
	The following descriptions of the discrete time implementation are informational.	
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes	

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)		
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.		
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2		
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH		
	Figure 17-4—OFDM training structure		
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.		

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD} $ (17-20)			
	The normalization factor, K _{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 1	7-6—Modulation-depend	lent normalization facto	or K _{MOD}
		Modulation	K_{MOD}	
	BPSK 1			
	QPSK 1/√2			
	16-QAM 1/√10			
	64-QAM 1/√42			
	See, e.g., 802.11-2007 § 17.3.5.7			

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007	
	17.3.5.8 Pilot subcarriers	
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.	
	See, e.g., 802.11-2007 § 17.3.5.8	

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA} n(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

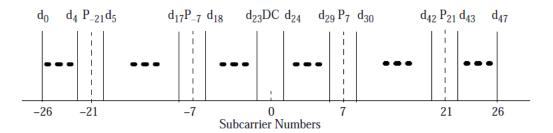


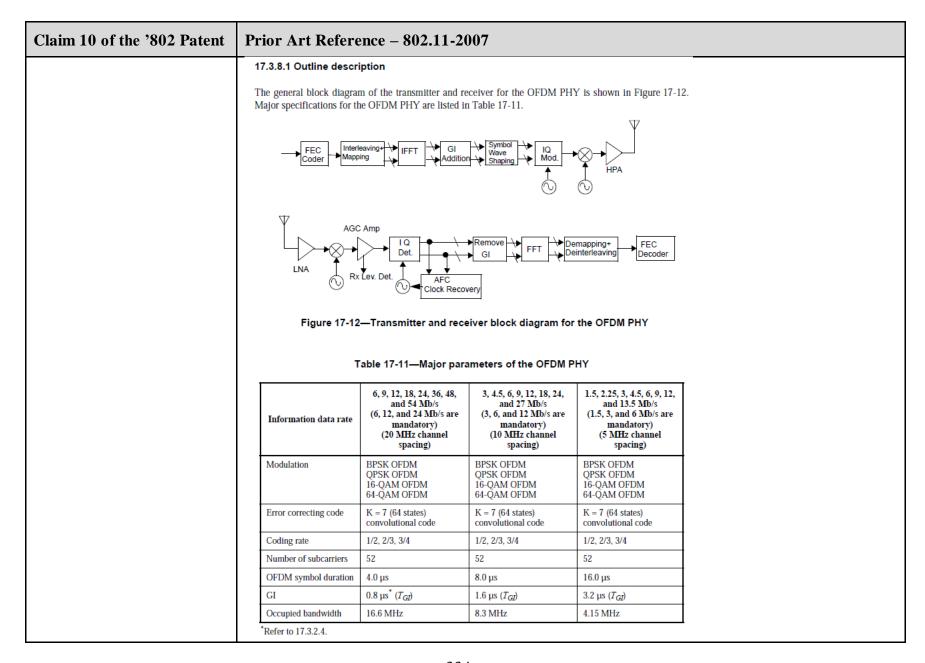
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

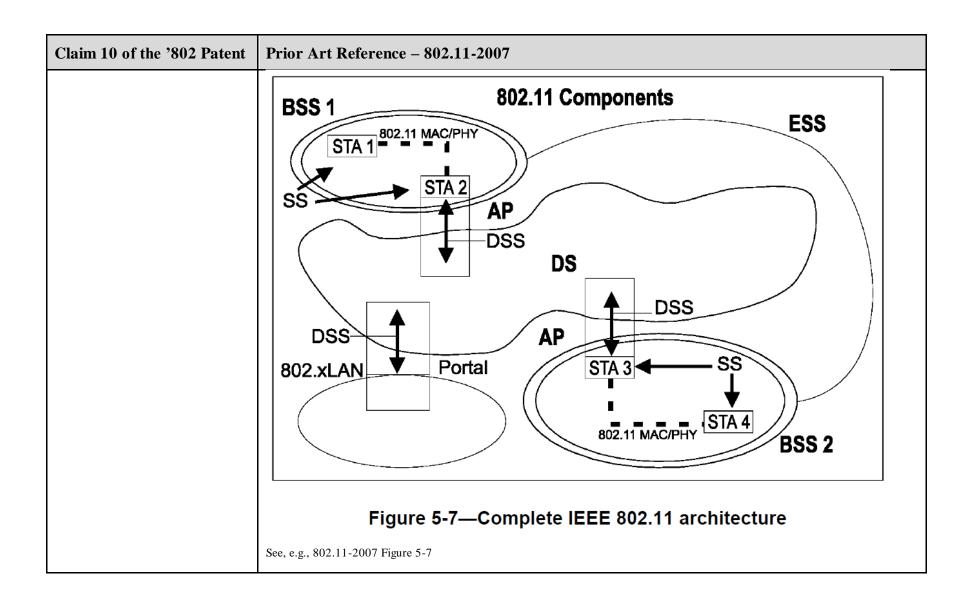
Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

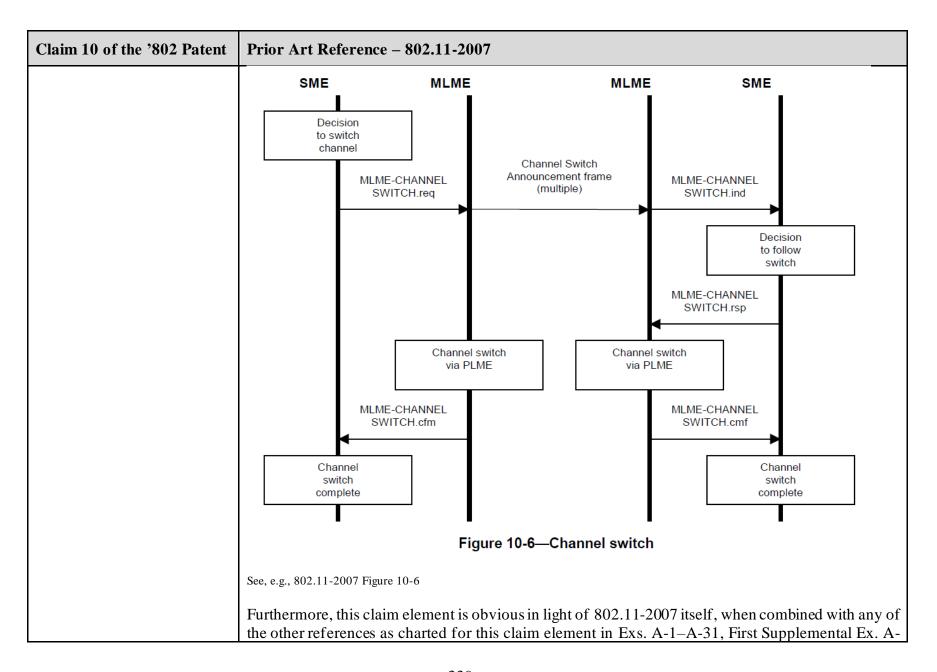


Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007				
	I.2.2 Transmit power levels				
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.				
	Table I.4—Transmit power level by regulatory domain				
	Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)		
	5.15–5.25	40 (2.5 mW/MHz)	200 mW		
	5.25-5.35	200 (12.5 mW/MHz)	200 mW		
	5.470-5.725	_	1 W		
	5.725–5.825	800 (50 mW/MHz)	_		
	Table I.5—U.S. public safety transmit power levels by regulatory domain U.S. public safety (mW)				
	Table I.5—U.S. public s Frequency band (GHz)				
	Frequency band	U.S. public safety (mV	V) 5 MHz		

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007		
	I.2.3 Transmit spectrum mask		
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.		
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt		
	Typical Signal Spectrum (an example)		
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)		
	Figure I.1—Transmit spectrum mask		
	See, e.g., 802.11-2007 § I.2.3		





Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and
510.77	First Supplemental Ex. A-Obviousness Chart.
[10.7] up-converting the second analog signal to a second RF center frequency greater than the first center RF frequency to produce a second up-converted analog signal, wherein the second up-	802.11-2007 discloses "up-converting the second analog signal to a second RF center frequency greater than the first center RF frequency to produce a second up-converted analog signal, wherein the second up-converted analog signal comprises a second up-converted frequency range from the second RF center frequency minus one-half the second frequency range to the second RF center frequency plus one-half the second frequency range, and wherein a frequency difference between the first RF center frequency and the second RF center frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range." See, e.g.:
converted analog signal comprises a second up-converted frequency range from the second RF center frequency minus one-half the	1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1
second frequency range to the second RF center frequency plus one-half the second frequency range, and wherein a frequency difference	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
between the first RF center frequency and the second RF center frequency is greater	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
than the sum of one-half the first frequency range and one-half the second frequency	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
range;	 a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation
	f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay, aPreambleLength,

aPLCPHeaderLength, aMPDUDurationFactor,

aMPDUMaxLength, aCWmin, aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Туре	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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Nau	ne Type	Description
aRxTxSwitchT	îme integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnT	ime integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffT	ime integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagatio	onTime integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessi	ingDelay integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIES) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLen	gth integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeader	Length Integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value Is rounded up to the next higher value.
aMPDUDurati	onFactor integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) \times 10 3)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer μ_S : aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor \times 8 \times PSDUoctets) / 10 9) + (8 \times PSDUoctets) / data rate where data rate is in Mb/s. The total time (in μ_S) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor \times 8 \times N) / 10 9 + (8 \times N) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxL	ength integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. C) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NOBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. b) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the order of the Number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarrier
	See, e.g., 602.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μ s ($T_{SHORT} + T_{LONG}$)
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 μ s ($T_{GI} + T_{FFT}$)	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (T _{FFT} /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 $\mu s (10 \times T_{FFT}/4)$
	T_{LONG} : Long training sequence duration	8 $\mu s (T_{GI2} + 2 \times T_{FFT})$	16 μ s ($T_{GI2} + 2 \times T_{FFT}$)	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$
	See, e.g., 802.11-2007 § 17.3.2.3		•	

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(i)} = Re\{r(t)\exp(j2\pi f_c t)\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations	
	The following descriptions of the discrete time implementation are informational.	
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes	

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ev}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD} $ (17-20)			
	The normalization factor, K _{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 17-6—Modulation-dependent normalization factor K _{MOD}			
	1	Modulation	K_{MOD}	
		BPSK	1	
		QPSK	1/√2	
		16-QAM	1/√10	
		64-QAM	1/√42	
	See, e.g., 802.11-2007 § 17.3.5.7			

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	17.3.5.8 Pilot subcarriers		
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.		
	See, e.g., 802.11-2007 § 17.3.5.8		

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

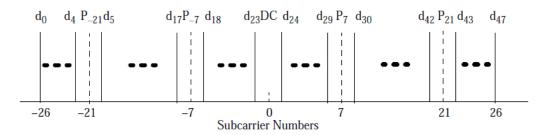


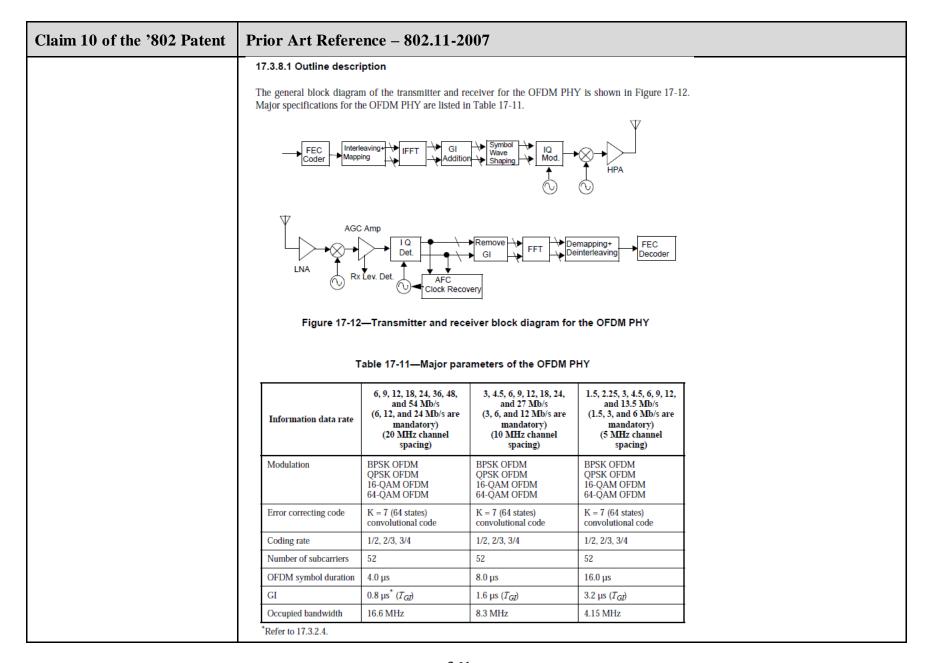
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

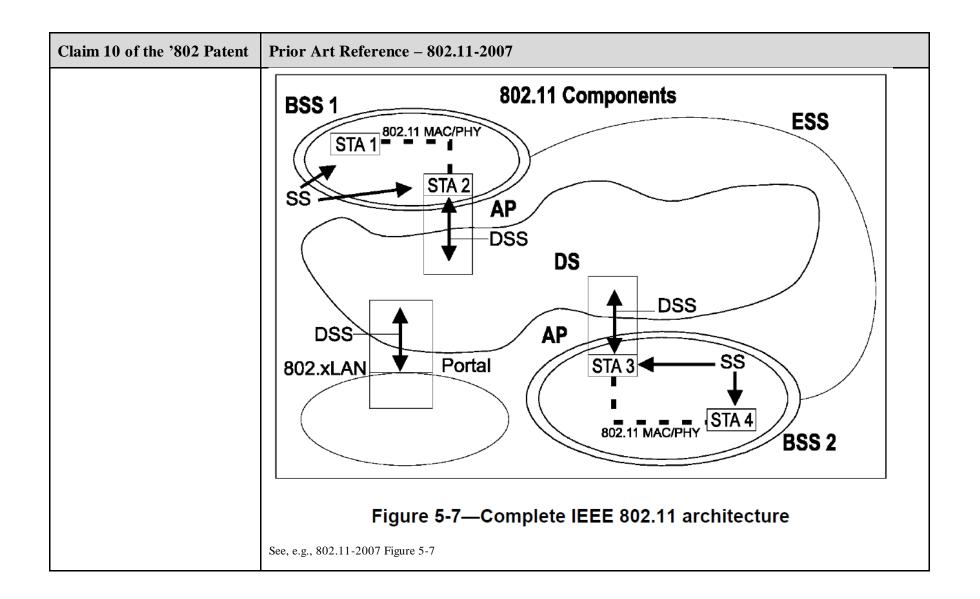
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	See, e.g., 802.11-2007 § 17.3.5.9

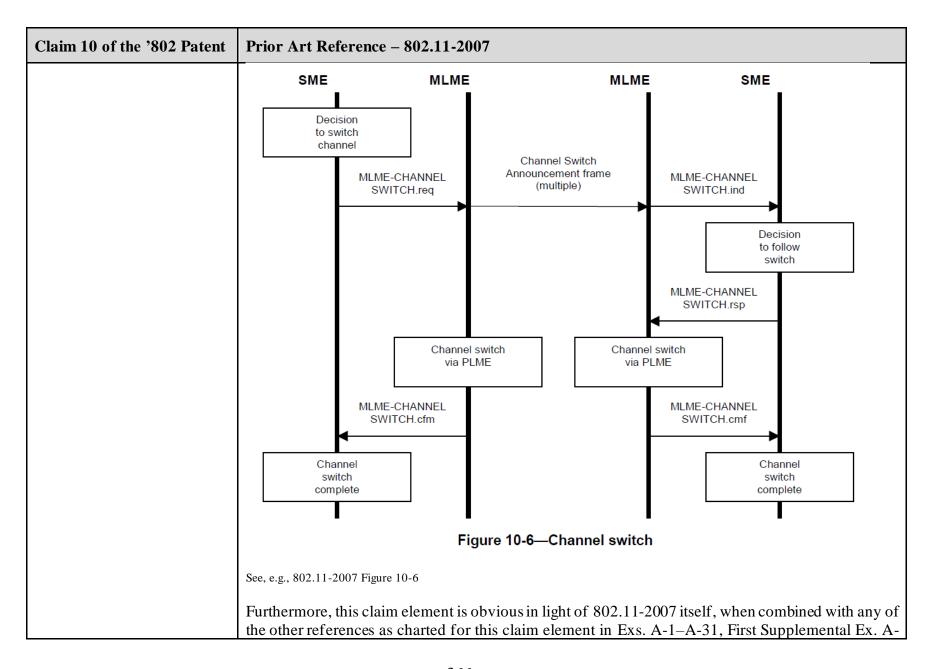


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

	r by regulatory domain (exce egulatory domain for the U.S. nsmit power level by regu	4.9 GHz public safety ba	Table I.4. The and is shown in
	nsmit power level by regu	ulatory domain	
Frequency band (GHz)	United States (Maximum output power v up to 6 dBi antenna gain (mW)		
5.15-5.25	40 (2.5 mW/MHz)	200 mW	\neg
5.25–5.35	200 (12.5 mW/MHz)	200 mW	
5.470-5.725	_	1 W	
5.725-5.825	800 (50 mW/MHz)	_	
Table I.5—U.S. public s Frequency band (GHz)		Fety (mW)	ain
4.94–4.99 low power			
-			
		Frequency band (GHz) 20 MHz channels channel channel channel 24.94–4.99 low power 100 50 4.94–4.99 high power 2000 1000	Frequency band (GHz) 20 MHz 10 MHz 5 MHz channels 4.94–4.99 low power 100 50 25

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	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





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[10.8] combining the first upconverted analog signal and the second upconverted analog signal to produce a combined upconverted signal;	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "combining the first up-converted analog signal and the second up-converted analog signal to produce a combined up-converted signal." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE 84 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made t
	g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

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	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

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	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description	
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.	
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.	
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.	
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.	
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrmraroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.	
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).	
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.	

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Na	me Type	Description
aRxTxSwitch	Time integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOn7	Time integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOff	Time integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagati	ionTime integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcess	singDelay integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIES) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTIme. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLe	ngth integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeade	rLength integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurai	tionFactor integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate] ((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength, + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxi	Length integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction		
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.		
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.		
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.		
	See, e.g., 802.11-2007 § 17.1		
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:		
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for		

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	prepending a Gl as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NOBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. b) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. b) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers swill be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP.					
	Table 17-4—Timing-related parameters					
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)		
	N _{SD} : Number of data subcarriers	48	48	48		
	N_{SP} : Number of pilot subcarriers	4	4	4		
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})		
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)		
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$		
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$		
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)		
	T_{GI} : GI duration	0.8 μs (T _{FFT} /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)		
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)		
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)		

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	Value Value Value Parameter (20 MHz channel (10 MHz channel spacing) spacing) spacing) Value Value Value (5 MHz channel spacing)							
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 $\mu s (10 \times T_{FFT}/4)$				
	T_{LONG} : Long training sequence duration	8 $\mu s (T_{GI2} + 2 \times T_{FFT})$	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$				
	See, e.g., 802.11-2007 § 17.3.2.3							

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(\phi)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GIZ}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$			
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.			
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} (a)			
	$T = T_{GIZ} + 2T_{FFT}$ $T_{GUARD} = T_{GIZ}$ T_{FFT} T_{FFT} T_{TT} T_{TT} T_{TT} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for			
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)			

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	17.3.2.5 Discrete time implementation considerations			
	The following descriptions of the discrete time implementation are informational.			
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes			

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC) The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.			
	$8 + 8 = 16 \mu\text{s}$ $10 \times 0.8 = 8 \mu\text{s}$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \mu\text{s}$ $0.8 + 3.2 = 4.0 \mu\text$			
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize			
	Figure 17-4—OFDM training structure			
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.			

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G.12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping					
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).					
	$d = (I + jQ) \times K_{MOD}$			(17-20)		
	The normalization factor, K _{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.					
	Table 1	7-6—Modulation-depend	lent normalization facto	or K _{MOD}		
		Modulation	K_{MOD}			
		BPSK	1			
		QPSK 1/√2				
	16-QAM 1/√10					
	64-QAM 1/√42					
	See, e.g., 802.11-2007 § 17.3.5.7					

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	17.3.5.8 Pilot subcarriers In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

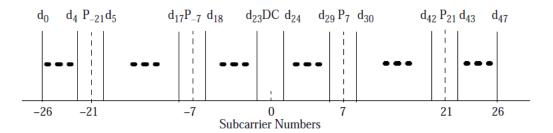


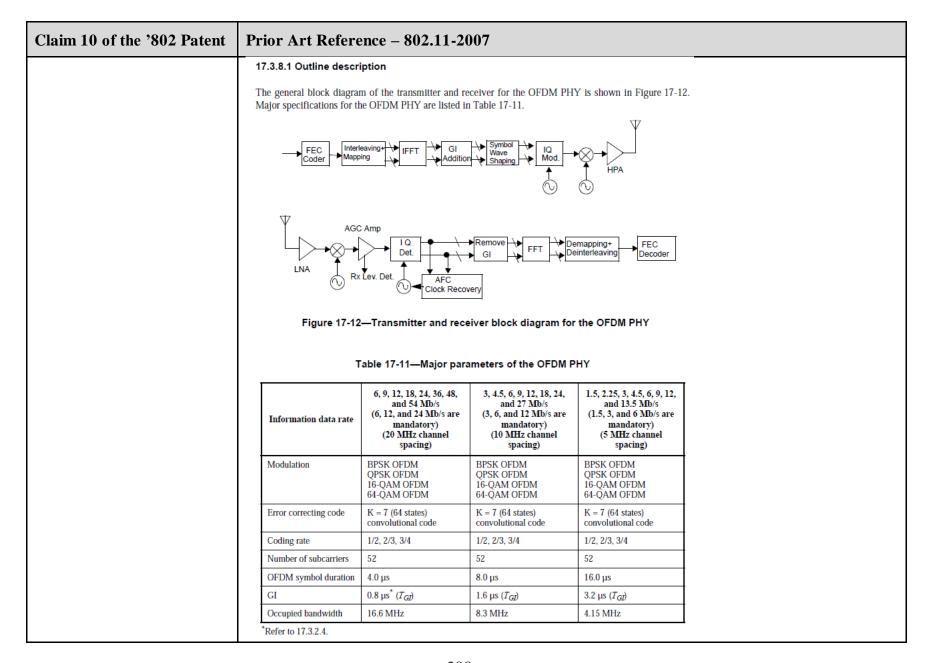
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

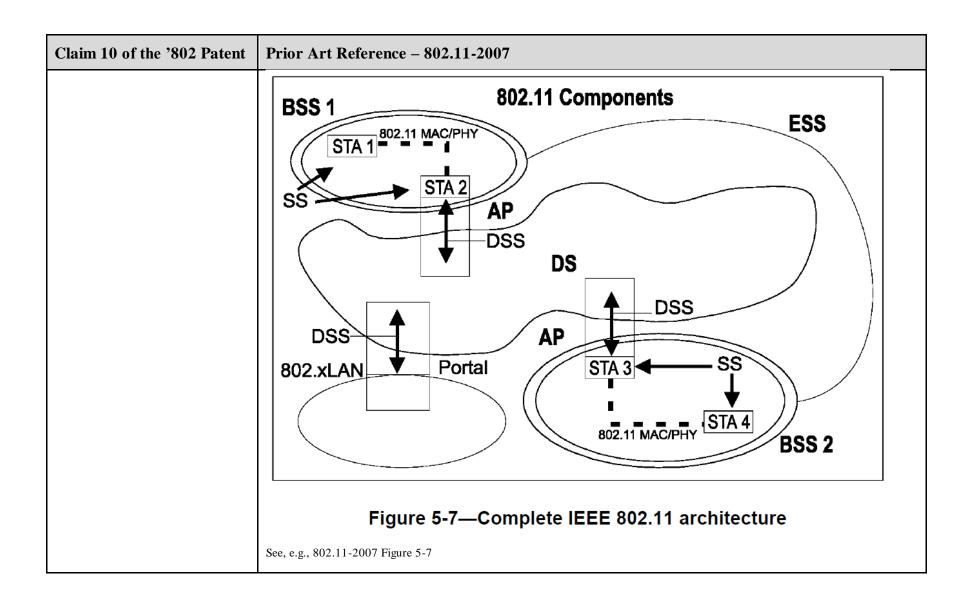
Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

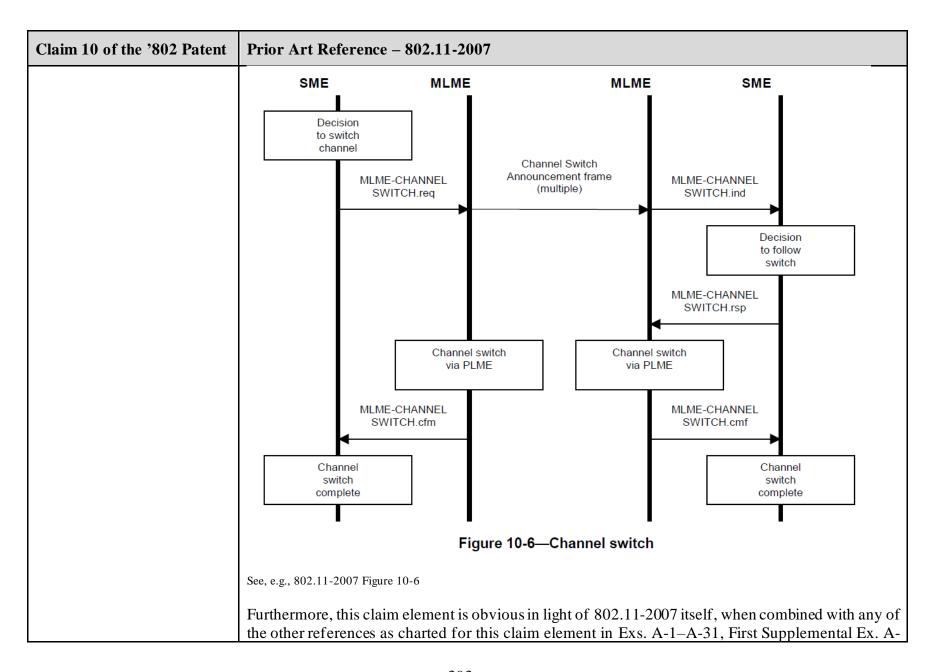


Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007							
	I.2.2 Transmit power levels							
		The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. $4.9\mathrm{GHz}$ public safety band is shown in Table I.5.						
		Table I.4—Transmit power level by regulatory domain						
		Frequency band (Maximum output power with Europe (GHz) up to 6 dBi antenna gain) (EIRP)						
		5.15-5.25	40 (2.5 m	W/MHz)	200 mW	٦		
		5.25-5.35	200 (12.5 mW/MHz)		200 mW			
		5.470-5.725	_		1 W			
		5.725–5.825	5 800 (50 mW/MHz) —					
	Tab	ole I.5—U.S. public sa		ower levels by S. public safety (m		ain		
		(GHz) 20 MHz 10 MHz 5 MHz channels channels						
		4.94–4.99 low power 100 50 25						
	4.94–4.99 high power 2000 1000 500							
	See, e.g., 802.11-2007 § I.2.2							

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative
	to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz) Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
[10.9] amplifying the combined up-converted signal in a power amplifier resulting in an amplified combined up-converted signal; and	Prior Art Reference – 802.11-2007 Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "amplifying the combined up-converted signal in a power amplifier resulting in an amplified combined up-converted signal." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE 8td 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance The PHYs used in IEEE 8td 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

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	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1 7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2). The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime, aPHY-RX-START-Delay, aRxTxTurnaroundTime, aTxPLCPDelay, aRxPLCPDelay, aRxTxSwitchTime, aTxRampOnTime, aTxRampOffTime, aTxRFDelay, aRxRFDelay, aAirPropagationTime, aMACProcessingDelay, aPreambleLength, aPLCPHeaderLength, aMPDUDurationFactor,

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

aMPDUMaxLength, aCWmin, aCWmax

Name	Туре	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Prior Art Refe	rence –	802.11-2007
Name	Туре	Description
aRxTxSwitchTime	Integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10°)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10°) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10°) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the
	PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
Claim 10 of the '802 Patent	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoded output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. i) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit group; convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex numbers string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM symbols one af
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (T _{FFT} /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)
	T_{LONG} : Long training sequence duration	8 μ s (T_{GI2} + 2 \times T_{FFT})	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(i)} = Re\{r(t)\exp(j2\pi f_c t)\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007	
	17.3.2.5 Discrete time implementation considerations	
	The following descriptions of the discrete time implementation are informational.	
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes	

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	$8 + 8 = 16 \mu\text{s}$ $10 \times 0.8 = 8 \mu\text{s}$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \mu\text{s}$ $0.8 + 3.2 = 4.0 \mu\text$
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{eff}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007 17.3.5.7 Subcarrier modulation mapping The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d_0 , are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20). $d = (I + jQ) \times K_{MOD} \qquad (17-20)$ The normalization factor, K_{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
				(17-20)
	described in 17.3.9.6.		conforms with the modulation	on accuracy requirements
	described in 17.3.9.6.	be used, as long as the device	conforms with the modulation	on accuracy requirements
	described in 17.3.9.6.	be used, as long as the device of the device	conforms with the modulation	on accuracy requirements
	described in 17.3.9.6.	ne used, as long as the device of the device	conforms with the modulation $oxed{k_{MOD}}$	on accuracy requirements
	described in 17.3.9.6.	17-6—Modulation-depend Modulation BPSK	lent normalization factor K _{MOD}	on accuracy requirements

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007		
	17.3.5.8 Pilot subcarriers		
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.		
	See, e.g., 802.11-2007 § 17.3.5.8		

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

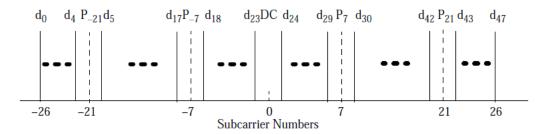


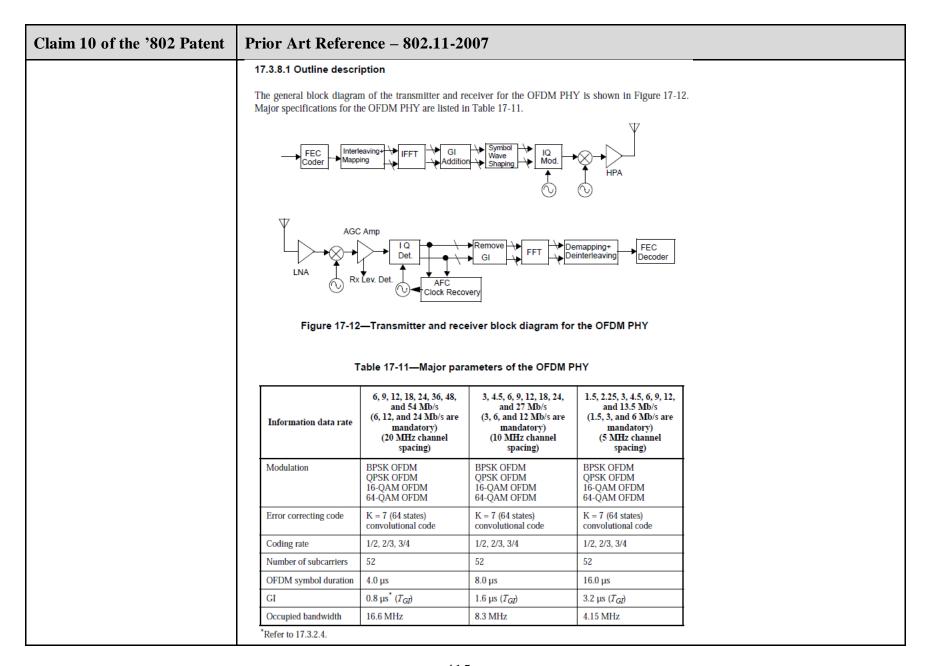
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

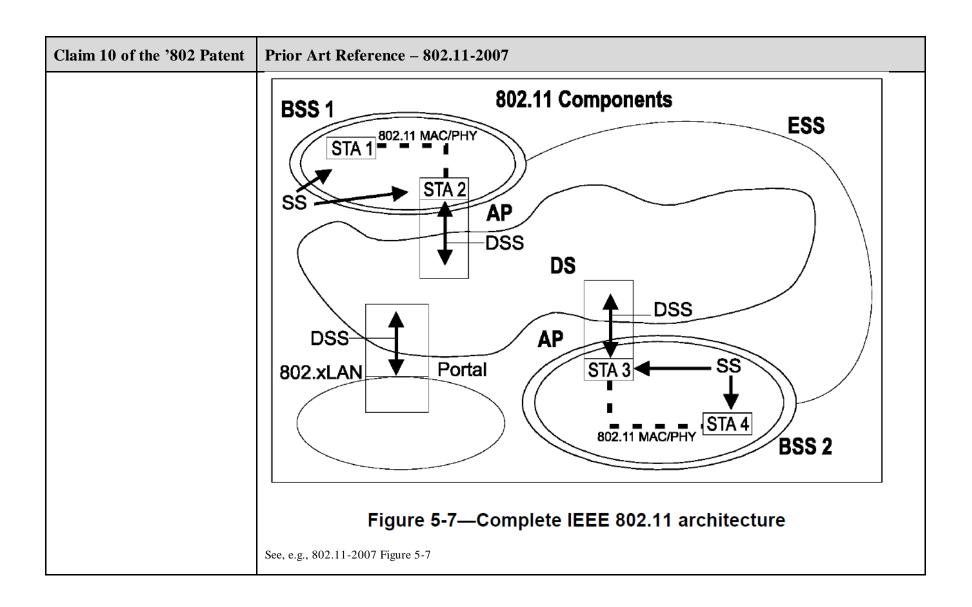
Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007	
	See, e.g., 802.11-2007 § 17.3.5.9	

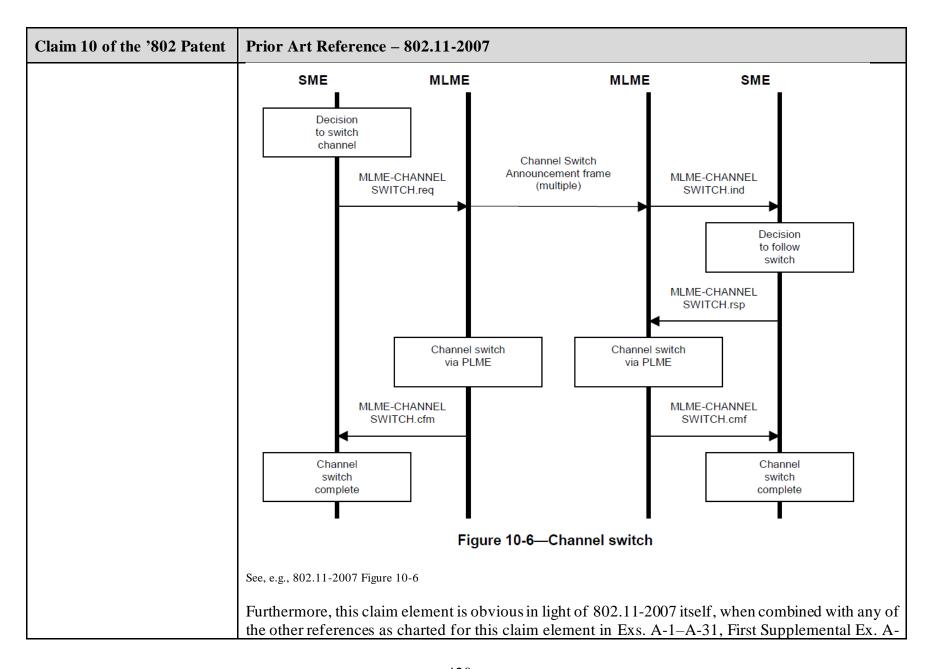


Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007					
	I.2.2 Transmit power levels					
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.					
		Table I.4—Transmit power level by regulatory domain				
		Frequency band (Maximum output power with Europe (GHz) up to 6 dBi antenna gain) (EIRP)				
		5.15-5.25	40 (2.5 mW/MHz)		200 mW	
		5.25-5.35	200 (12.5 mW/MHz)		200 mW	
		5.470-5.725	_		1 W	
		5.725–5.825 800 (50 mW/MHz)		_		
	Tak	Table I.5—U.S. public safety transmit power levels by regulatory domain U.S. public safety (mW) Frequency band				ain
		(GHz)	20 MHz channels	10 MHz channels	5 MHz channels	
		4.94–4.99 low power	100	50	25	
		4.94–4.99 high power 2000 1000		500		
	See, e.g., 802.11-2007 § I.2.2					

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall
	within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth. Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example) -28 dBr Typical Signal Spectrum (an example) -40 dBr
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





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	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.10] transmitting the amplified combined upconverted signal on a first antenna,	802.11-2007 discloses "transmitting the amplified combined up-converted signal on a first antenna." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.
	See, e.g., 802.11-2007 § 1.1
	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates. See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,

aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin, aCWmax

ac vi

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrmraroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTim	ne integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDe	elay integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIES) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTIme. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLengt	th integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFac	ctor integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate [aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of ooded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. b) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.5 for details. b) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers and the com
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N_{SD} : Number of data subcarriers	48	48	48
	N _{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)
	T _{LONG} : Long training sequence duration	8 $\mu s (T_{GI2} + 2 \times T_{FFT})$	16 µs $(T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)

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	17.3.2.4 Mathematical conventions in the signal descriptions	
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:	
	$r_{(RF)(i)} = Re\{r(t)\exp(j2\pi f_c t)\} $ (17-1)	
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency	
	The transmitted baseband signal is composed of contributions from several OFDM symbols.	
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$	
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.	
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.	
	$N_{ST}/2$	
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)	
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.	

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations	
	The following descriptions of the discrete time implementation are informational.	
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes	

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)	
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.	
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2	
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH	
	Figure 17-4—OFDM training structure	
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.	

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ev}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d_0 , are formed by multiplying the resulting (I+jQ) value by a normalization factor d_0 , as described in Equation (17-20). $d = (I+jQ) \times K_{MOD} \qquad (17-20)$ The normalization factor, d_0 , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			led into groups of <i>N_{BPSC}</i> (, 16-QAM, or 64-QAM constellation mappings, The output values, d, are
				(17-20)
		Ü		n accuracy requirements
		Ü		n accuracy requirements
		7-6—Modulation-depend	ent normalization factor	n accuracy requirements
		7-6—Modulation-depend	ent normalization factor K _{MOD}	n accuracy requirements
		7-6—Modulation-depend Modulation BPSK	lent normalization factor $\mathbf{K}_{ extbf{MOD}}$	n accuracy requirements

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	17.3.5.8 Pilot subcarriers	
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.	
	See, e.g., 802.11-2007 § 17.3.5.8	

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATAn}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

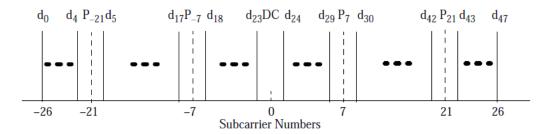


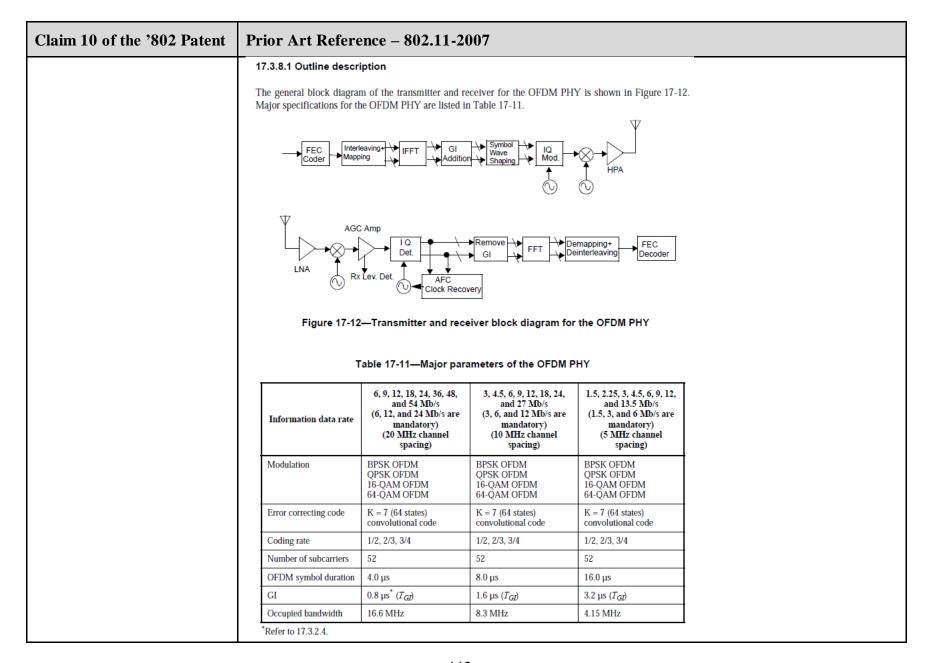
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

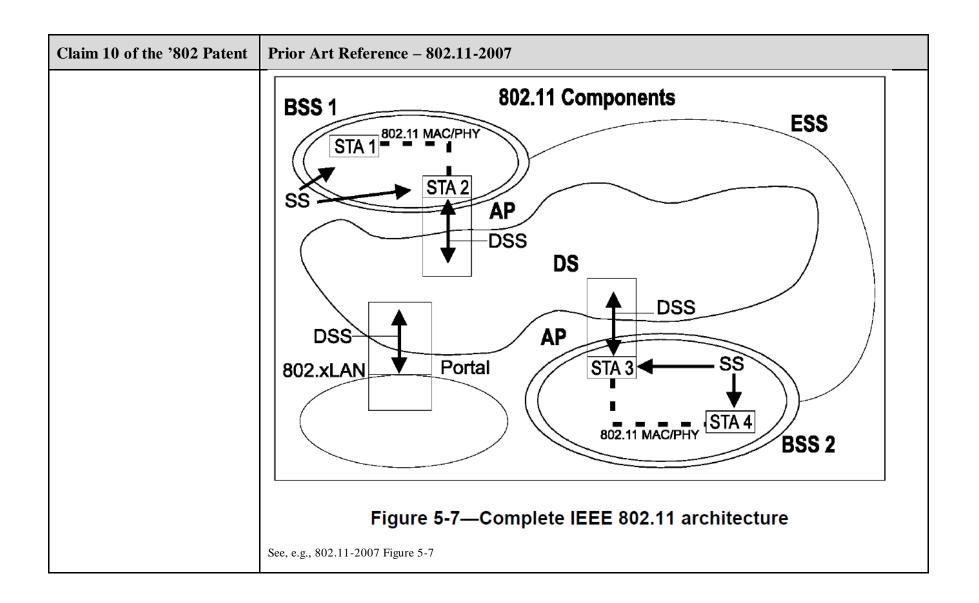
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	See, e.g., 802.11-2007 § 17.3.5.9

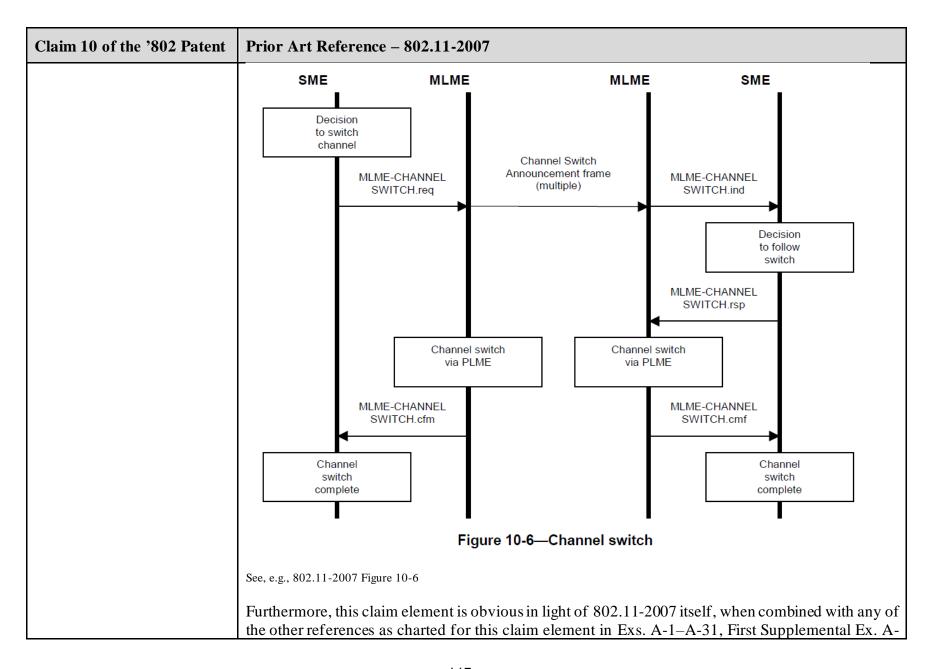


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

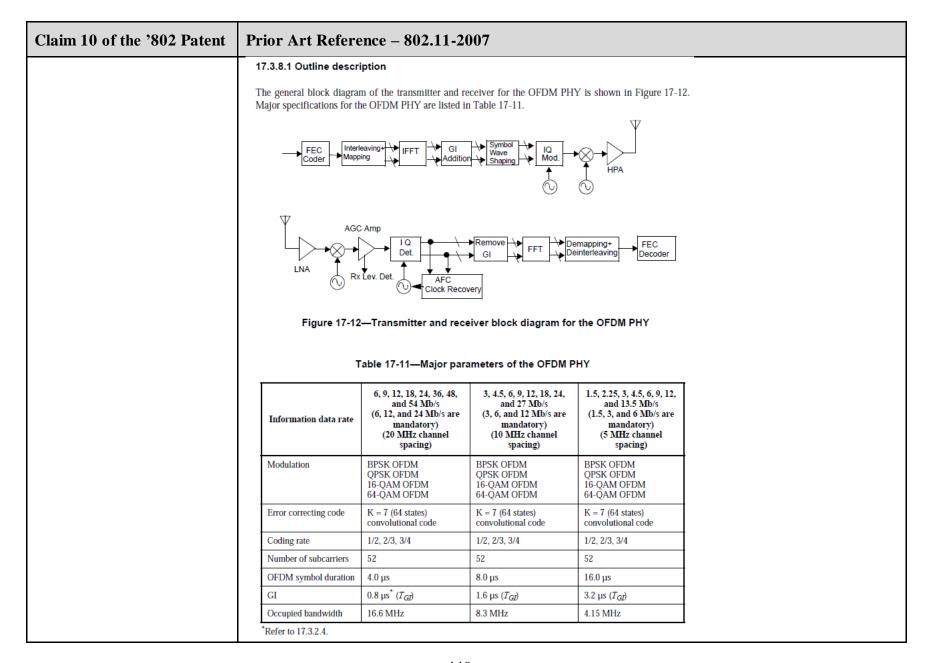
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	I.2.2 Transmit power levels				
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.				
	Table I.4—Transmit power level by regulatory domain				
	Frequency band (GHz)				
	5.15–5.25	40 (2.5 mW/MHz)	200 mW		
	5.25-5.35	200 (12.5 mW/MHz)	200 mW		
	5.470-5.725	_	1 W		
	5.725–5.825	800 (50 mW/MHz)	_		
	Table I.5—U.S. public safety transmit power levels by regulatory domain U.S. public safety (mW)				
	Table I.5—U.S. public s Frequency band (GHz)				
	Frequency band	U.S. public safety (mV	V) 5 MHz		

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007	
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative	
	to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.	
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt	
	Typical Signal Spectrum (an example)	
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz) Figure I.1—Transmit spectrum mask	
	See, e.g., 802.11-2007 § I.2.3	





Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[10.11] wherein the bandwidth of said power amplifier is greater than the difference between a lowest frequency in the first upconverted frequency range and a highest frequency in the second up-converted frequency range.	802.11-2007 discloses "wherein the bandwidth of said power amplifier is greater than the difference between a lowest frequency in the first up-converted frequency range and a highest frequency in the second up-converted frequency range." See, e.g.:



Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details.
	f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details.
	g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of <i>NCBPS</i> bits. Within each group, perform an
	"interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details.
	i) Divide the resulting coded and interleaved data string into groups of <i>NCBPS</i> bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details.
	j) Divide the complex number string into groups of 48 complex numbers. Each such group will be

Claim 10 of the '802 Patent	Prior Art Reference – 802.11-2007
	associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting "complex baseband" waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3).
	17.3.9.6.2 Transmitter spectral flatness The average energy of the constellations in each of the spectral lines -161 and +1 +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and +17 +26 will deviate no more than +2/-4 dB from the average energy of spectral lines -161 and +1 +16. The data for this test shall be derived from the channel estimation step.
	Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
[13.1] The method of claim 10	802.11-2007 discloses all the elements of claim 10 for all the reasons provided above.
[13.1] The method of claim 10 [13.2] wherein the first digital signal is encoded using a first wireless protocol and the second digital signal is encoded using a second wireless protocol.	802.11-2007 discloses all the elements of claim 10 for all the reasons provided above. 802.11-2007 discloses "wherein the first digital signal is encoded using a first wireless protocol and the second digital signal is encoded using a second wireless protocol." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs, in IEEE 8td 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance The PHYs used in IEEE 8td 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,

aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

		+
Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH. or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIES) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPS K or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

prepending a Gl as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scramble feer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string gonstitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambled zero bits following the will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoder bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.6 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers, Each such group will be associated with one OFDM symbol. In each group, the complex numbers, the number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.9 for details. j) For caach group of s	Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3). See, e.g., 802.11-2007 § 17.3.2.1		coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. i) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit group, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered to 47 and mapped hereafter into OFDM subcarriers numbered -26 to -22, -20 to -8, -6 to -1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers -21, -7, 7

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007				
	17.3.2.3 Timing related par	17.3.2.3 Timing related parameters			
	Table 17-4 is the list of timing p	parameters associated with	the OFDM PLCP.		
	1	Table 17-4—Timing-rela	ated parameters		
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	N _{SD} : Number of data subcarriers	48	48	48	
	N_{SP} : Number of pilot subcarriers	4	4	4	
	N _{ST} : Number of subcarriers, total	52 $(N_{SD} + N_{SP})$	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)	
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs (1/ Δ_F)	
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$	
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 μ s ($T_{GI} + T_{FFT}$)	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)	
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)	
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)	
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007				
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μ s (10 × T_{FFT} /4)	
	T_{LONG} : Long training sequence duration	8 μ s ($T_{GIZ} + 2 \times T_{FFT}$)	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$	

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)^{(i)}} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{\textit{PACKET}}(t) = r_{\textit{PREAMBLE}}(t) + r_{\textit{SIGNAL}}(t - t_{\textit{SIGNAL}}) + r_{\textit{DATA}}(t - t_{\textit{DATA}}) \tag{17-2}$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0,80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d_0 , are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20). $d = (I+jQ) \times K_{MOD} \qquad (17-20)$ The normalization factor, K_{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6. Table 17-6—Modulation-dependent normalization factor K_{MOD}			
				(17-20)
				or K _{MOD}
		Modulation	K_{MOD}	
		BPSK	1	
	QPSK $1/\sqrt{2}$ 16-QAM $1/\sqrt{10}$ 64-QAM $1/\sqrt{42}$			
	See, e.g., 802.11-2007 § 17.3.5.7			

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007	
	17.3.5.8 Pilot subcarriers	
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.	
	See, e.g., 802.11-2007 § 17.3.5.8	

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

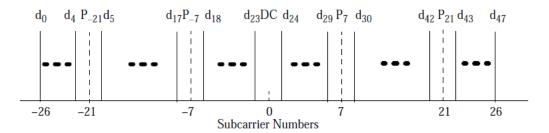


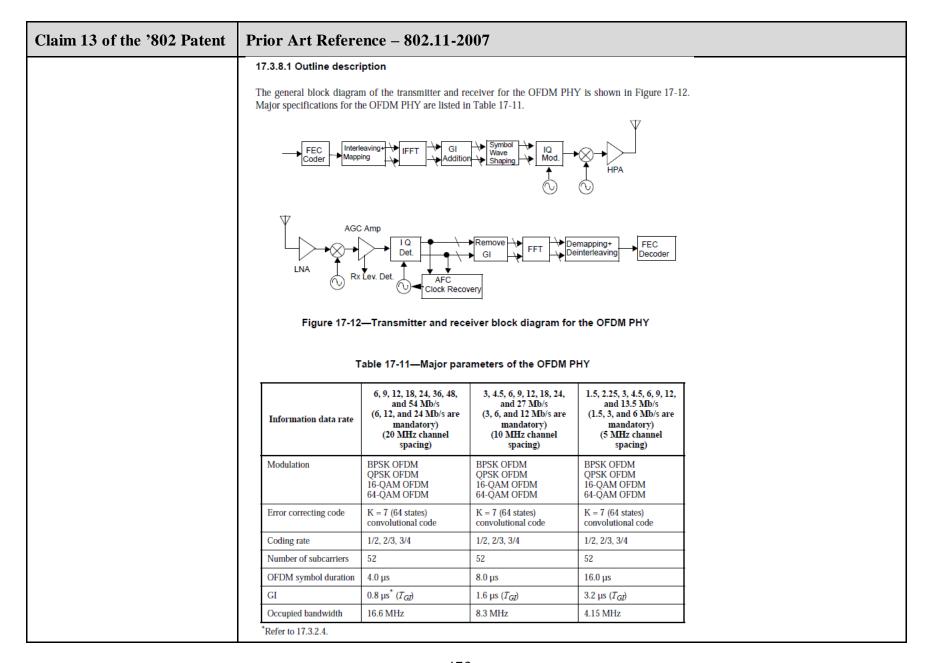
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

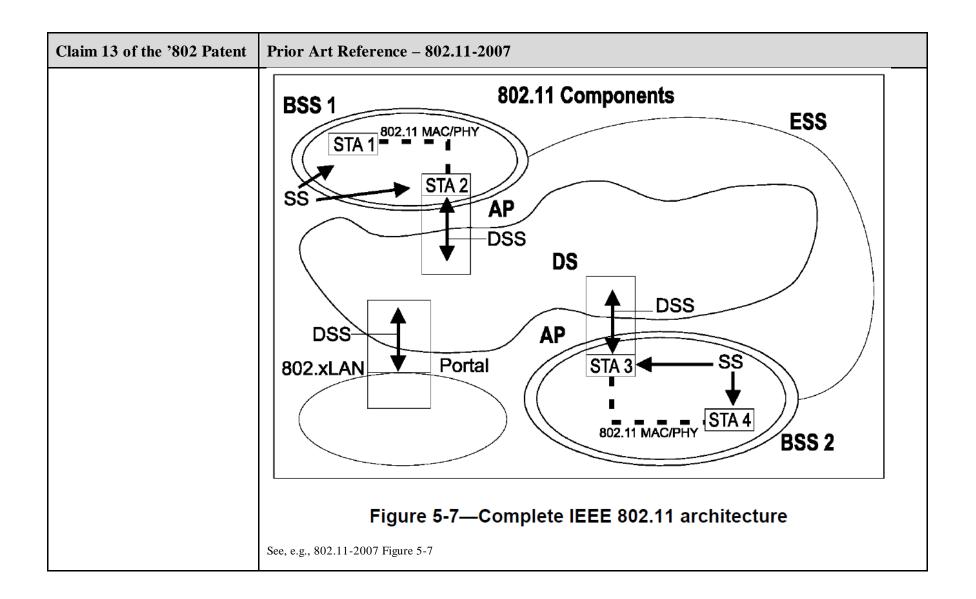
Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007	
	See, e.g., 802.11-2007 § 17.3.5.9	

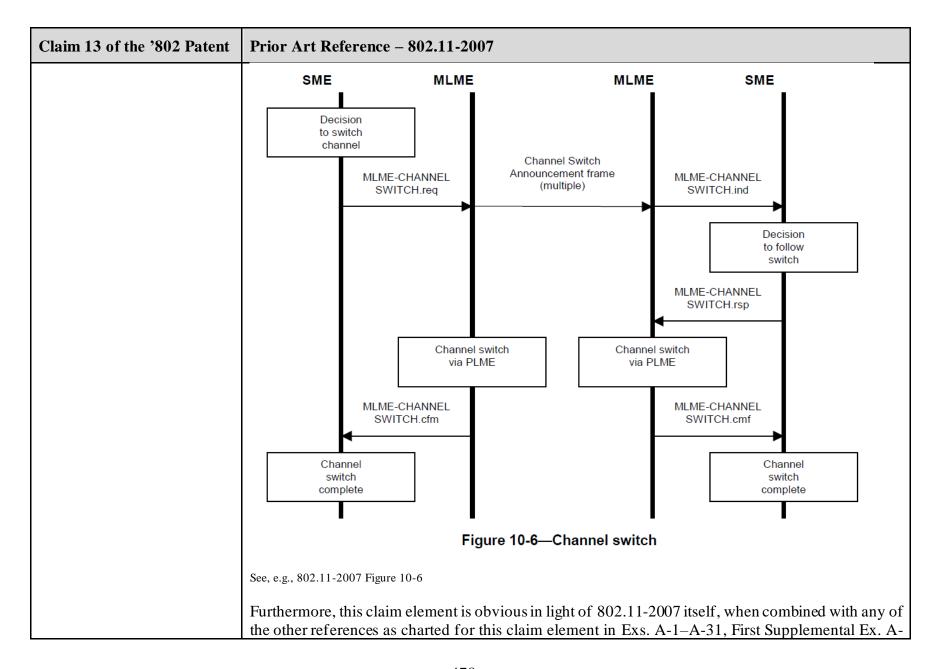


Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007	
	See, e.g., 802.11-2007 § 17.3.8.1	
	17.3.8.3.1 Operating frequency range	
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.	
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.	
	See, e.g., 802.11-2007 § 17.3.8.3.1	
	17.3.9.1 Transmit power levels	
	The maximum allowable transmit power by regulatory domain is defined in Annex I.	
	See, e.g., 802.11-2007 § 17.3.9.1	
	17.3.9.6.2 Transmitter spectral flatness	
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.	
	See, e.g., 802.11-2007 § 17.3.9.6.2	

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007				
	I.2.2 Transmit power levels				
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.				
	Table I.4—Transmit power level by regulatory domain				
	Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)		
	5.15–5.25	40 (2.5 mW/MHz)	200 mW		
	5.25–5.35	200 (12.5 mW/MHz)	200 mW		
	5.470-5.725	5.470-5.725 —			
	5.725–5.825	800 (50 mW/MHz)	_		
	Table I.5—U.S. public safety transmit power levels by regulatory domain U.S. public safety (mW)				
	Table I.5—U.S. public Frequency band (GHz)				
	Frequency band	U.S. public safety (m ¹ 20 MHz 10 MHz	W) 5 MHz		

Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 13 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
[14.1] The method of claim 10	802.11-2007 discloses all the elements of claim 10 for all the reasons provided above.
[14.2] wherein the second data is the same as the first data, the method further comprising:	802.11-2007 discloses "wherein the second data is the same as the first data, the method further comprising." See, e.g.: 1.1 Scope
	The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1
	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only)
	DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,

aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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Name	Туре	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the Issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the last chip of the symbol for DS, or 1/2
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIES) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTIme. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[(IPPDUbits/PSDUbits)-1) × 10°)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10°) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPS K or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the
	PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subscarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. e) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.5 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.5 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters				
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters				
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	N _{SD} : Number of data subcarriers	48	48	48	
	N_{SP} : Number of pilot subcarriers	4	4	4	
	N_{ST} : Number of subcarriers, total	52 $(N_{SD} + N_{SP})$	52 (N _{SD} + N _{SP})	$52 (N_{SD} + N_{SP})$	
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)	
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs (1/ Δ_F)	
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$	
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 μ s ($T_{GI} + T_{FFT}$)	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 $\mu s (T_{GI} + T_{FFT})$	
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)	
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)	
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μ s (10 × T_{FFT} /4)
	T_{LONG} : Long training sequence duration	8 µs $(T_{GI2} + 2 \times T_{FFT})$	16 μs $(T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$

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	17.3.2.4 Mathematical conventions in the signal descriptions	
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:	
	$r_{(RF)^{(i)}} = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1)	
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency	
	The transmitted baseband signal is composed of contributions from several OFDM symbols.	
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ (17-2)	
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.	
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.	
	$N_{ST}/2$	
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)	
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.	

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations	
	The following descriptions of the discrete time implementation are informational.	
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes	

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0,80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)	
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.	
	$8 + 8 = 16 \mu\text{s}$ $10 \times 0.8 = 8 \mu\text{s}$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \mu\text{s}$ $10 \times 0.8 + 3.2 = 4.0 \mu\text{s}$ $10 \times 0.8 + 3.2 = 4.$	
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize	
	Figure 17-4—OFDM training structure	
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.	

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A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

(17-8)

where

$$T_{G.12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD} $ (17-			
	that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 17-6—Modulation-dependent normalization factor K _{MOD}			or K _{MOD}
	Modulation K _{MOD}			
		BPSK	1	
		QPSK	1/√2	
		16-QAM	1/√10	
	64-QAM 1/√42			
	See, e.g., 802.11-2007 § 17.3.5	5.7		

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	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

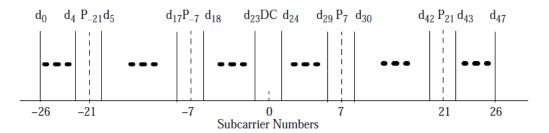


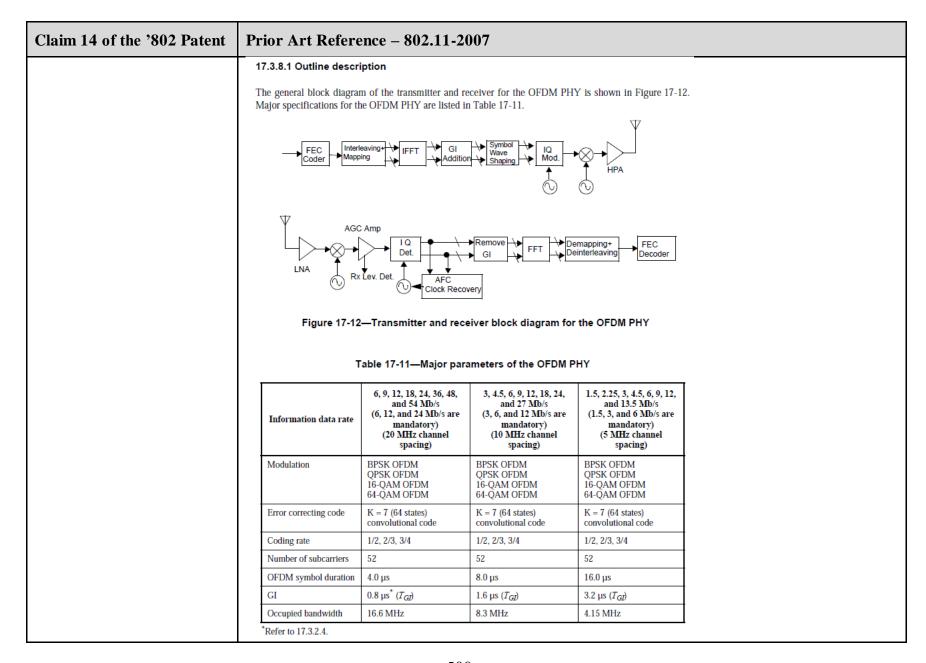
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

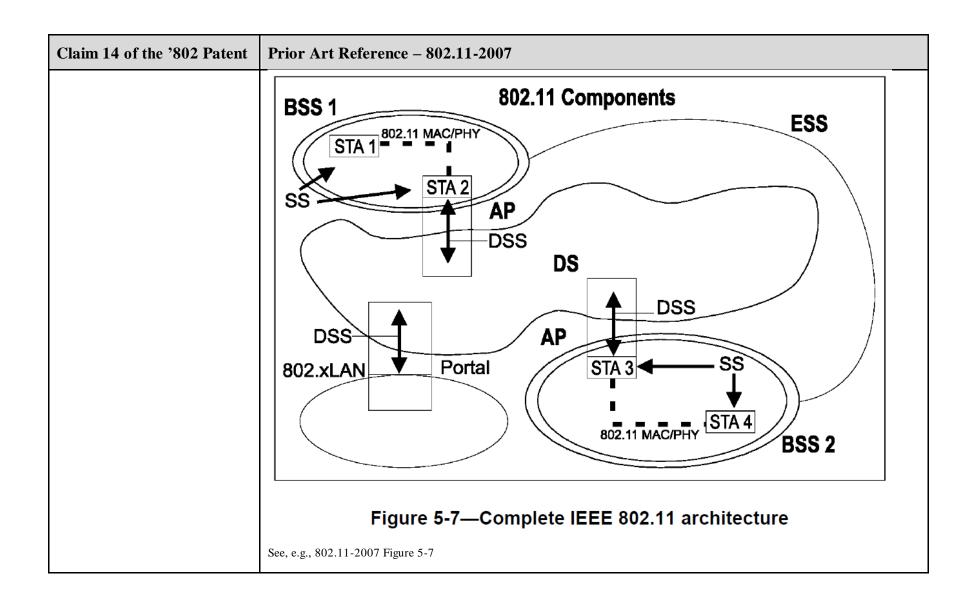
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	See, e.g., 802.11-2007 § 17.3.5.9		

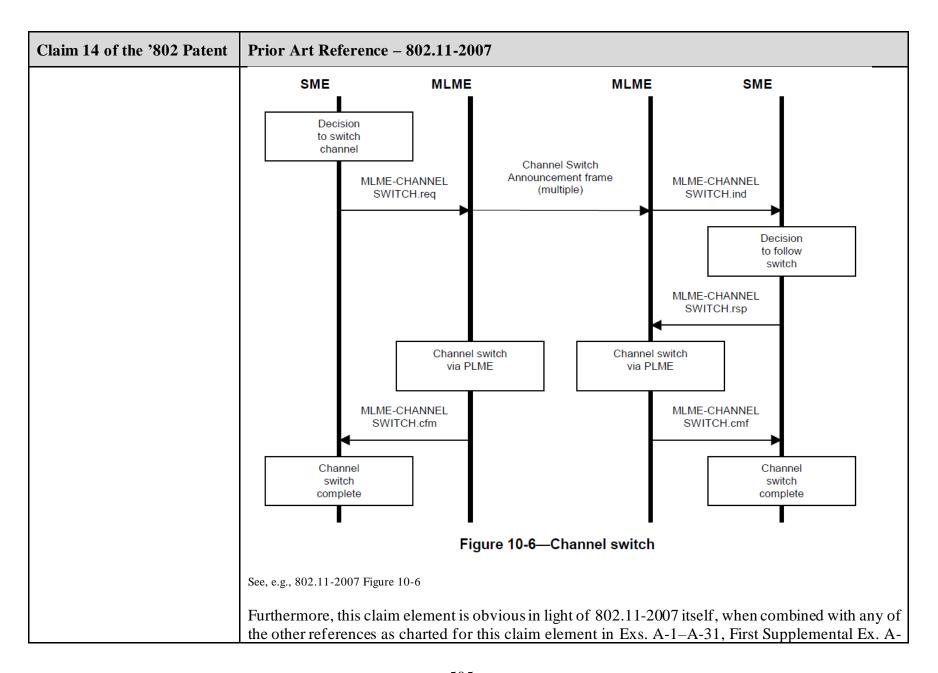


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

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	I.2.2 Transmit power levels							
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.							
	Table I.4—Transmit power level by regulatory domain							
		Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)		Europe (EIRP)			
		5.15-5.25	40 (2.5 mW/MHz)		200 mW	٦		
		5.25–5.35	200 (12.5 mW/MHz)		200 mW			
		5.470-5.725	_		1 W			
		5.725-5.825	800 (50 mW/MHz)		_			
	Table I.5—U.S. public safety transmit power levels by regulatory domain U.S. public safety (mW) Frequency band							
		(GHz)	20 MHz channels	10 MHz channels	5 MHz channels			
		4.94–4.99 low power	100	50	25			
		4.94–4.99 high power	2000	1000	500			
	See, e.g., 802.11-2007 § I.2.2							
	See, e.g., 802.11-2	UU / § 1.2.2						

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	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example) -40 dBr
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





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	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[14.3] receiving the	802.11-2007 discloses "receiving the transmitted signal on a second antenna." See, e.g.:
transmitted signal on a second	
antenna;	1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.
	See, e.g., 802.11-2007 § 1.1
	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood

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	that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11

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	definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability.

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	 — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20 10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime, aPHY-RX-START-Delay, aRxTxTurnaroundTime, aTxPLCPDelay, aRxPLCPDelay, aRxTxSwitchTime, aTxRampOnTime, aTxRampOffTime, aTxRFDelay, aRxRFDelay, aAirPropagationTime, aMACProcessingDelay, aPreambleLength, aPLCPHeaderLength, aMPDUDurationFactor, aMPDUMaxLength, aCWmin, aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH. or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to Issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength, + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPS K or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the
	PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subscarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. e) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. e) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.5 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.5 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP.			
	Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	<i>T_{SYM}</i> : Symbol interval	4 μs $(T_{GI} + T_{FFT})$	8 μ s (T_{GI} + T_{FFT})	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × <i>T_{FFT}</i> /4)
	T_{LONG} : Long training sequence duration	8 μ s ($T_{GIZ} + 2 \times T_{FFT}$)	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(i)} = Re\{r\langle t\rangle \exp(j2\pi f_c t)\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{\rm ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GI2} + 2T_{FFT}$ T_{GUARD} $-T_{GI2}$ T_{FFT} T_{FFT} T_{TFT} T_{TR} T_{TR} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007		
	17.3.3 PLCP preamble (SYNC)		
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.		
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2		
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH		
	Figure 17-4—OFDM training structure		
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.		

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A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ev}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G.12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD}$			
	The normalization factor, K _{MOD} , depends on the base modulation mother than the modulation type can be different from the start to the end of the			
	The normalization factor, K _{MOD} , depends on the base modulation mothat the modulation type can be different from the start to the end of the from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the same average power for all mappings. In practical implementation ormalization factor can be used, as long as the device conforms with described in 17.3.9.6.	he transmission, as the signal changes e normalization factor is to achieve the tions, an approximate value of the		
	that the modulation type can be different from the start to the end of the from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the same average power for all mappings. In practical implementation ormalization factor can be used, as long as the device conforms with	he transmission, as the signal changes e normalization factor is to achieve the tions, an approximate value of the the modulation accuracy requirements		
	that the modulation type can be different from the start to the end of the from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the same average power for all mappings. In practical implementation ormalization factor can be used, as long as the device conforms with described in 17.3.9.6.	he transmission, as the signal changes e normalization factor is to achieve the tions, an approximate value of the the modulation accuracy requirements eation factor K _{MOD}		
	that the modulation type can be different from the start to the end of the from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the same average power for all mappings. In practical implementar normalization factor can be used, as long as the device conforms with described in 17.3.9.6. Table 17-6—Modulation-dependent normalization-dependent normalization-	he transmission, as the signal changes e normalization factor is to achieve the tions, an approximate value of the the modulation accuracy requirements eation factor K _{MOD}		
	that the modulation type can be different from the start to the end of the from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the same average power for all mappings. In practical implementar normalization factor can be used, as long as the device conforms with described in 17.3.9.6. Table 17-6—Modulation-dependent normalization Modulation K _{MO}	the transmission, as the signal changes in normalization factor is to achieve the tions, an approximate value of the the modulation accuracy requirements that the modulation factor K _{MOD}		
	that the modulation type can be different from the start to the end of the from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the same average power for all mappings. In practical implementation normalization factor can be used, as long as the device conforms with described in 17.3.9.6. Table 17-6—Modulation-dependent normalization Modulation BPSK 1	the transmission, as the signal changes in normalization factor is to achieve the stions, an approximate value of the sthe modulation accuracy requirements that the modulation factor K _{MOD}		

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	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8	

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

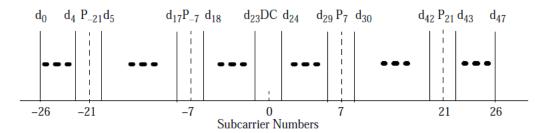


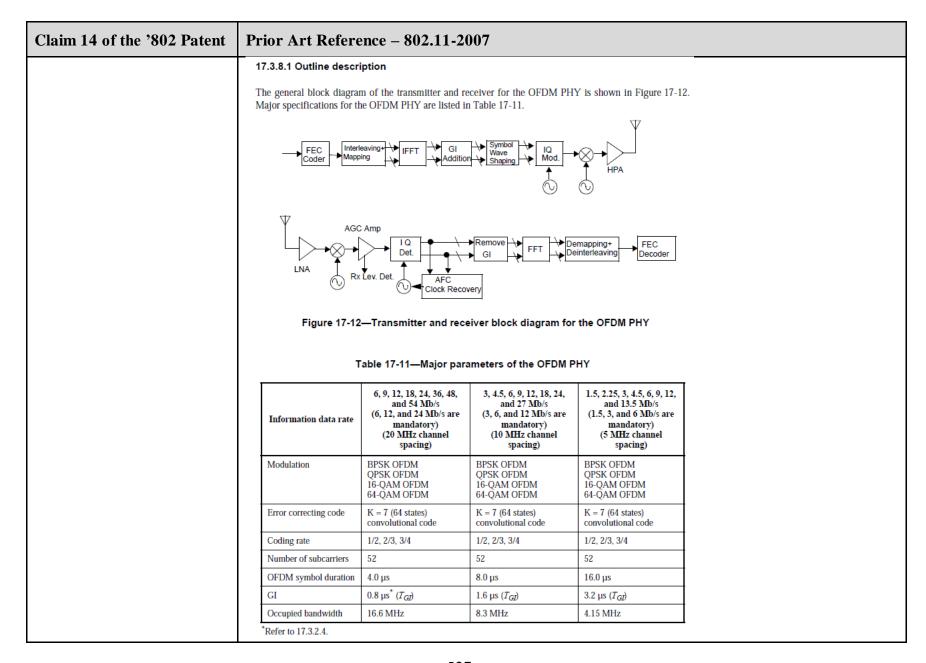
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
 (17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

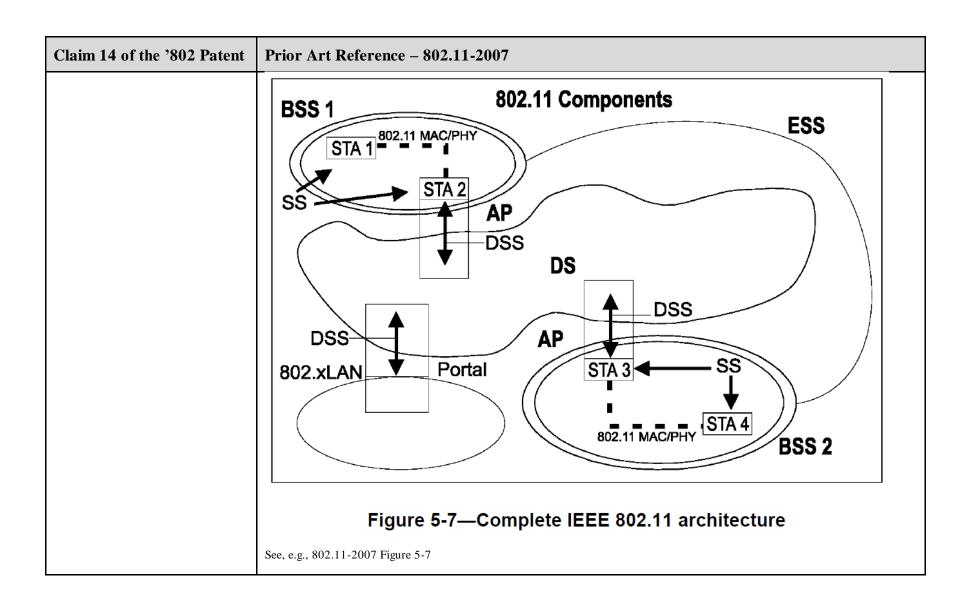
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	See, e.g., 802.11-2007 § 17.3.5.9	

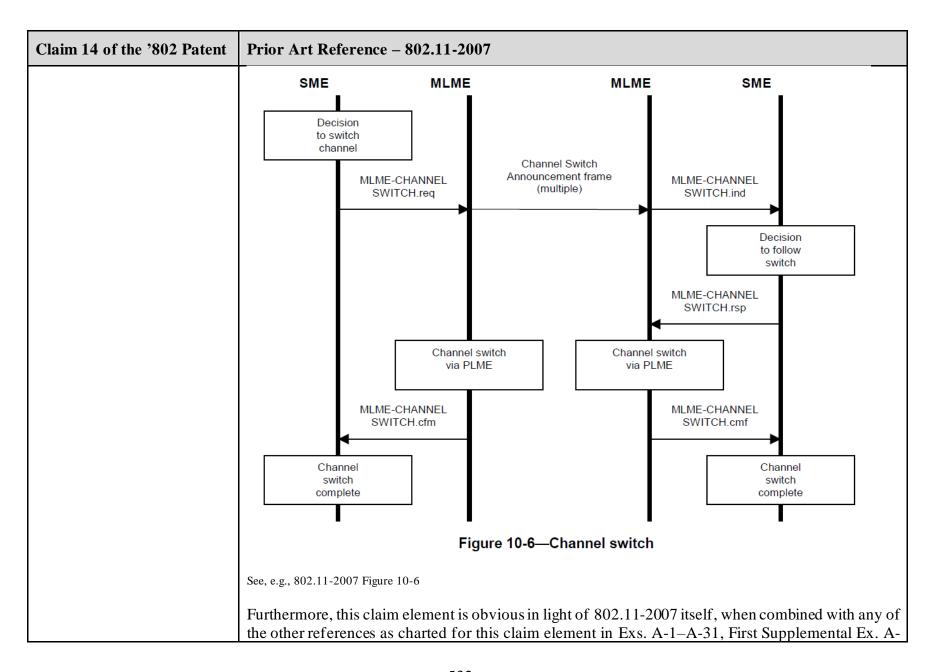


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

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	I.2.2 Transmit power levels The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5. Table I.4—Transmit power level by regulatory domain					
	Fre	equency band (GHz)	United (Maximum out) up to 6 dBi ai (mV	put power with ntenna gain)	Europe (EIRP)	
		5.15–5.25	40 (2.5 m	W/MHz)	200 mW	1
		5.25–5.35 200 (12.5 mW/MHz)		200 mW		
	!	5.470–5.725 —		1 W		
	!	5.725–5.825 800 (50 mW/MHz)		_		
		I.5—U.S. public sat		·	regulatory domair	1
		Frequency band	U.S	5. public safety (mV	V)	
		Frequency band (GHz)	U.S 20 MHz channels	5. public safety (mV 10 MHz channels	5 MHz channels	
	4		20 MHz	10 MHz	5 MHz	

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	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr
	at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example) -40 dBr
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask See, e.g., 802.11-2007 § I.2.3





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	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[14.4] amplifying the received signal in a low noise amplifier resulting in an amplified received up-converted signal, wherein the bandwidth of said	802.11-2007 discloses "amplifying the received signal in a low noise amplifier resulting in an amplified received up-converted signal, wherein the bandwidth of said low noise amplifier is greater than the difference between the lowest frequency in the first up-converted frequency range and the highest frequency in the second up-converted frequency range." See, e.g.:
low noise amplifier is greater than the difference between the lowest frequency in the first up-converted frequency	1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1
range and the highest frequency in the second up- converted frequency range;	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other)
	f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping

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	areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used

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	to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

a Tx Ramp On Time,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin, aCWmax

ac vi

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description		
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.		
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.		
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.		
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.		
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTUTARAOUNTIME: aTXPLCPDelay + aRXTXSWitchTime + aTXRAMPONTIME + aTXRFDelay.		
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).		
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.		

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Name	Туре	Description	
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.	
aTxRampOnTime	Integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.	
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifler off.	
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH. or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).	
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.	
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.	
aMACProcessingDel	ay Integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.Indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.	
aPreambleLength	Integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.	
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.	
aMPDUDurationFac	for integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUOc	
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).	
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.	
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.	

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the
	PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers associated
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related para	ameters		
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP.			
	Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	<i>T_{SYM}</i> : Symbol interval	4 μs $(T_{GI} + T_{FFT})$	8 μ s (T_{GI} + T_{FFT})	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × <i>T_{FFT}</i> /4)
	T_{LONG} : Long training sequence duration	8 μ s ($T_{GIZ} + 2 \times T_{FFT}$)	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)

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	17.3.2.4 Mathematical conventions in the signal descriptions	
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:	
	$r_{(RF)(i)} = Re\{r(t)\exp(j2\pi f_c t)\}$ (17-1)	
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency	
	The transmitted baseband signal is composed of contributions from several OFDM symbols.	
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ (17-2)	
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.	
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.	
	$N_{ST}/2$	
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)	
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.	

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GI2} + 2T_{FFT}$ T_{GUARD} $= T_{GI2}$ T_{FFT} T_{FFT} T_{TR} T_{TR} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	$8 + 8 = 16 \mu\text{s}$ $10 \times 0.8 = 8 \mu\text{s}$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \mu\text{s}$ $10 \times 0.8 + 3.2 = 4.0 \mu\text{s}$ $10 \times 0.8 + 3.2 = 4.$
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

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A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier mo	odulation mapping		
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD}$			(17-20)
	The normalization factor, K _{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 1	7-6—Modulation-depend	lent normalization facto	or K _{MOD}
		Modulation	K_{MOD}	
		BPSK	1	
		QPSK	1/√2	
		16-QAM	1/√10	
		64-QAM	1/√42	
	See, e.g., 802.11-2007 § 17.3.5.7			

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	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{cases} N_{SD}^{-1} \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k)\Delta_{F}(t-T_{GI})) \\ N_{ST}^{/2} \\ + p_{n+1} \sum_{k=-N_{ST}^{/2}} P_{k} \exp(j2\pi k\Delta_{F}(t-T_{GI})) \\ k = -N_{ST}^{/2} \end{cases}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

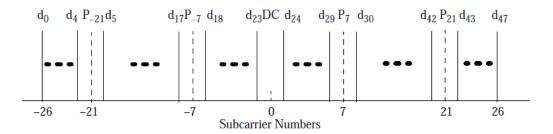


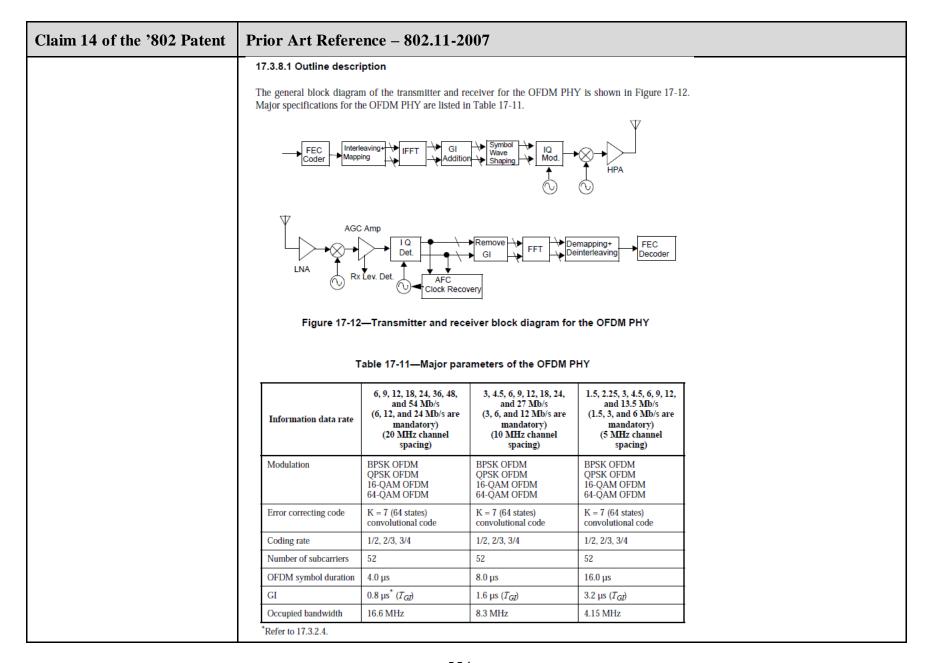
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

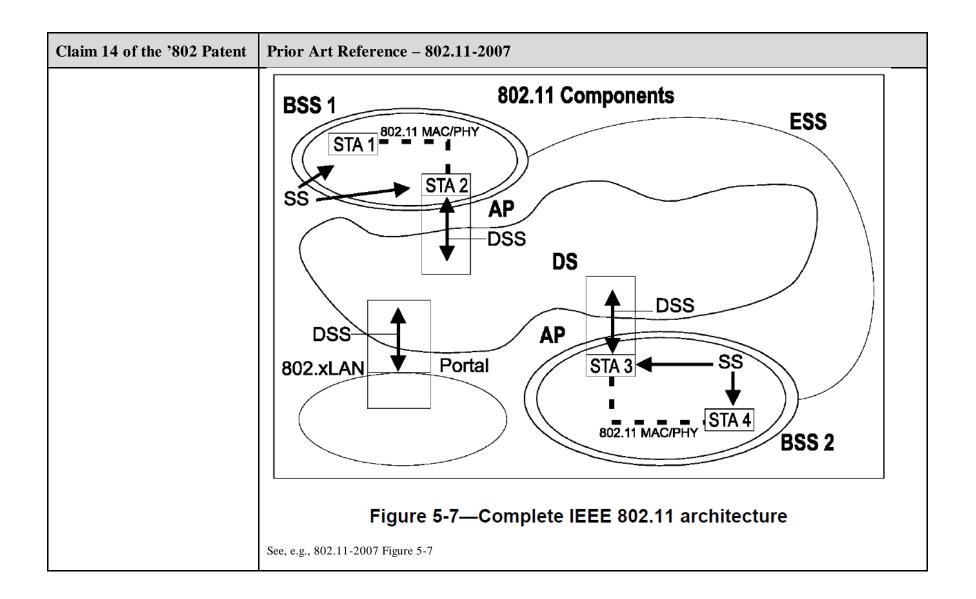
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	See, e.g., 802.11-2007 § 17.3.5.9

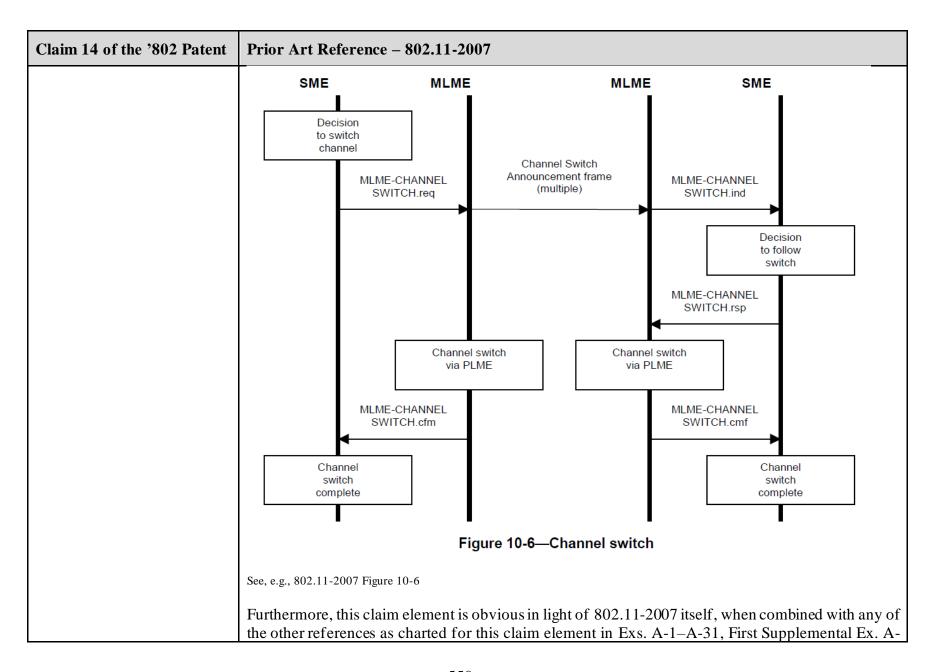


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

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	I.2.2 Transmit power levels The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.					
		Table I.4—Tran	smit power leve	l by regulatory	/ domain	
		Frequency band (GHz)	United S (Maximum outpo up to 6 dBi ant (mW	ut power with tenna gain)	Europe (EIRP)	
		5.15-5.25	40 (2.5 mW/MHz)		200 mW	1
		5.25-5.35	200 (12.5 mW/MHz)		200 mW	1
		5.470-5.725	_		1 W	1
		5.725-5.825	800 (50 mV	V/MHz)	_	_
	Tak	5.725–5.825 ble I.5—U.S. public sa	· · · · · · · · · · · · · · · · · · ·		regulatory domair	1
		Fraguency band	U.S.	public safety (m\	V)	
		Frequency band (GHz)	U.S. 20 MHz channels	public safety (mV 10 MHz channels	V) 5 MHz channels	
			20 MHz	10 MHz	5 MHz	

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	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





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[14.5] down-converting the amplified received upconverted signal using a first down-converter and a signal corresponding to the first RF center frequency to produce a fourth analog signal corresponding to the first analog signal; and	Prior Art Reference – 802.11-2007 Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "down-converting the amplified received up-converted signal using a first down-converter and a signal corresponding to the first RF center frequency to produce a fourth analog signal corresponding to the first analog signal." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wirel LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the Besign of wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the Besign of wired LANs, an address are addressed to the physical location of the
	g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

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	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

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	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

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	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1 7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay, aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

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N	ame Type	Description	1
aRxTxSwitc	hTime integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.	
aTxRampOr	Time integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.	
aTxRampOf	fTime integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.	
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).	
aRxRFDelay	/ integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the Issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.	
aAirPropaga	tionTime integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.	
aMACProce	ssingDelay integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.Indication primitive (for response after SIFS) or PHY-CCA.Indication (IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.	
aPreambleLo	ength integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.	
aPLCPHead	erLength integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value Is rounded up to the next higher value.	
aMPDUDur	ationFactor integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate] ((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer us: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.	
aMPDUMax	Length integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).	
aCWmin	Integer	The minimum size of the CW, in units of aSlotTime.	
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.	1

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single PDSV, another the subsequently mapped onto a single PDSV.
	single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. C) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.1 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers and
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP.				
	Table 17-4—Timing-related parameters				
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	N _{SD} : Number of data subcarriers	48	48	48	
	N_{SP} : Number of pilot subcarriers	4	4	4	
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)	
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$	
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$	
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)	
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)	
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)	
	<i>T_{SYM}</i> : Symbol interval	4 μs $(T_{GI} + T_{FFT})$	8 μ s (T_{GI} + T_{FFT})	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μ s (10 × T_{FFT} /4)	
	T_{LONG} : Long training sequence duration	8 µs $(T_{GI2} + 2 \times T_{FFT})$	16 μs $(T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$	

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)^{(i)}} = Re\{r\langle t\rangle \exp(j2\pi f_c t)\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} (a)
	$T = T_{GI2} + 2T_{FFT}$ T_{GUARD} $= T_{GI2}$ T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

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A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$S_{-26, 26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, -1-j, 0, 0, 0, -$$

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 14 of the '802 Patent	Prior Art Reference –	802.11-2007			
	17.3.5.7 Subcarrier modulation mapping				
	RATE requested. The enco (1, 2, 4, or 6) bits and con constellation points. The illustrated in Figure 17-10	oded and interleaved binary so iverted into complex number conversion shall be perform by, with the input bit, b ₀ , being	serial input data shall be or rs representing BPSK, Q ed according to Gray-co g the earliest in the strea	$^{\circ}$ 64-QAM, depending on the divided into groups of N_{BPSC} PSK, 16-QAM, or 64-QAM ded constellation mappings, m. The output values, d, are tor K_{MOD} , as described in	
	$d = (I + jQ) \times K_{MOD}$			(17-20)	
	that the modulation type of from SIGNAL to DATA, a same average power for	an be different from the star as shown in Figure 17-1. The all mappings. In practic	t to the end of the transm e purpose of the normaliz al implementations, an	escribed in Table 17-6. Note dission, as the signal changes station factor is to achieve the approximate value of the lation accuracy requirements	
	Table 17-6—Modulation-dependent normalization factor K _{MOD}				
	1	Modulation	K _{MOD}	7	
		BPSK	1	7	
		QPSK	1/√2	1	
		16-QAM	1/√10		
		64-QAM	1/√42	_	
	See, e.g., 802.11-2007 § 17.3.5	.7			

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

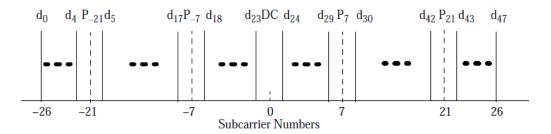


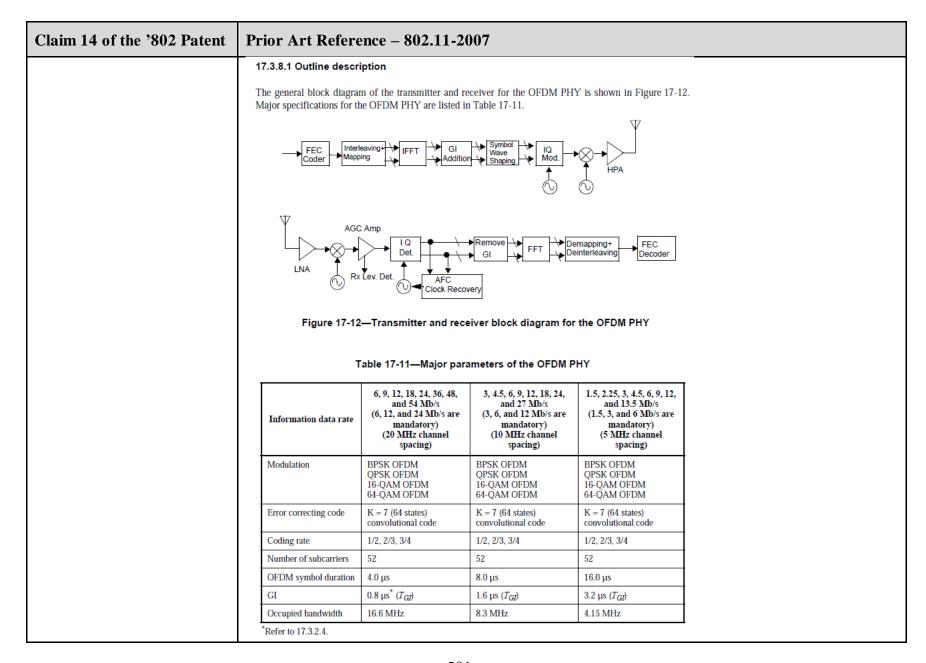
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

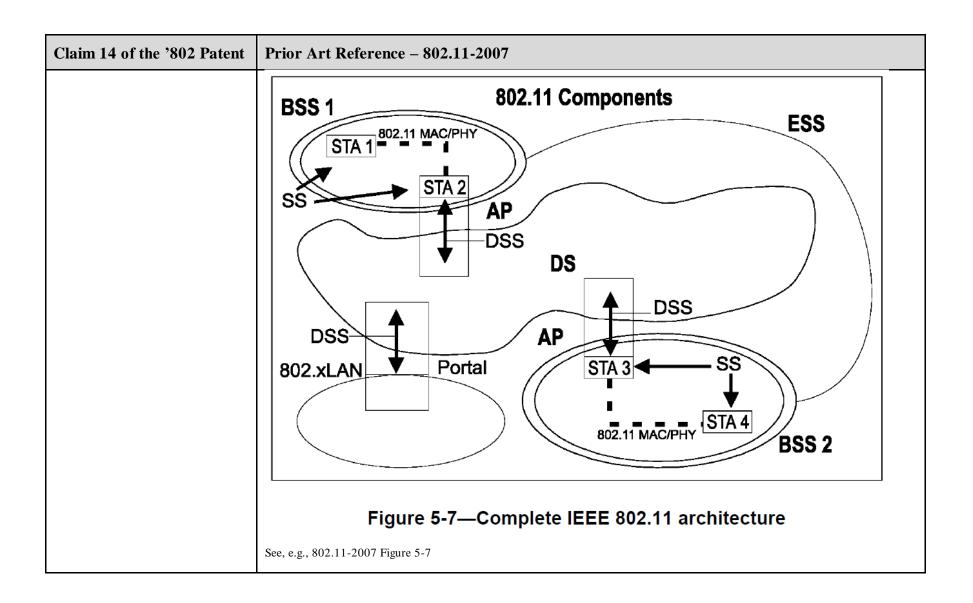
Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

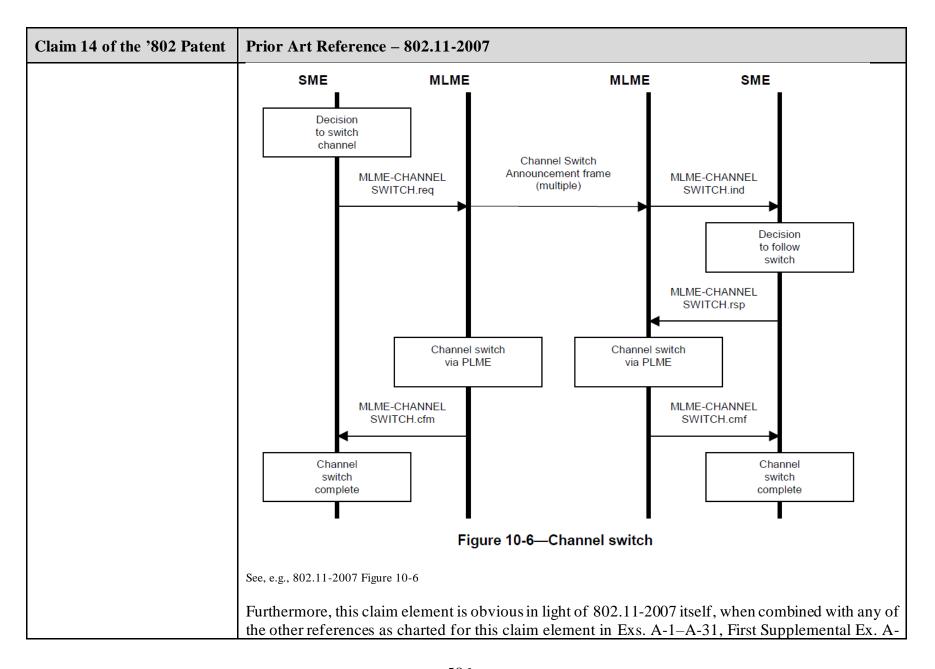


Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 14 of the '802 Patent	Prior Art Ref	erence – 802.11-200	7			
	I.2.2 Transn	nit power levels				
		allowable output power wable output power by reફ				
		Table I.4—Tran	smit power leve	l by regulatory	/ domain	
		Frequency band (GHz)	United S (Maximum outpo up to 6 dBi ant (mW	ut power with tenna gain)	Europe (EIRP)	
		5.15-5.25	40 (2.5 mW	//MHz)	200 mW	1
		5.25-5.35	200 (12.5 m ³	W/MHz)	200 mW	1
		5.470-5.725	_		1 W	1
		5.725-5.825	800 (50 mW/MHz)		_	
	Tak	Table I.5—U.S. public safety transmit power levels by regulatory doma				1
		Fraguency band	U.S.	public safety (m\	V)	
		Frequency band (GHz)	U.S. 20 MHz channels	public safety (mV 10 MHz channels	V) 5 MHz channels	
			20 MHz	10 MHz	5 MHz	

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr
	at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example) -40 dBr
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask See, e.g., 802.11-2007 § I.2.3





Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
[14.6] down-converting the amplified received upconverted analog signal using a second down-converter and a signal corresponding to the second RF center frequency to produce a fifth analog signal corresponding to the second analog signal.	Prior Art Reference – 802.11-2007 Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill in the art. For the motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "down-converting the amplified received up-converted analog signal using a second down-converter and a signal corresponding to the second RF center frequency to produce a fifth analog signal corresponding to the second analog signal." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific for adio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are know
	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled en vironments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,

aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

a Tx Ramp Off Time,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin, aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrmraroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Prior Art Refe	rence –	802.11-2007
Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	Integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIES) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	Integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10°)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10°) + (8 × PSDUOct
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers are number
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related para	17.3.2.3 Timing related parameters		
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	<i>T_{SYM}</i> : Symbol interval	4 μs $(T_{GI} + T_{FFT})$	8 μ s (T_{GI} + T_{FFT})	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 $\mu s (10 \times T_{FFT}/4)$	
	T _{LONG} : Long training sequence duration	8 μ s ($T_{GI2} + 2 \times T_{FFT}$)	16 μ s ($T_{GI2} + 2 \times T_{FFT}$)	32 µs $(T_{GI2} + 2 \times T_{FFT})$	
	See, e.g., 802.11-2007 § 17.3.2.3		•	·	

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(i)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 µs), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GIZ}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ $T_{GUARD} = T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0.80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12}))$$
(17-9)

where

$$T_{G.12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD}$			(17-20)
	The normalization factor, K_{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 1	7-6—Modulation-depend	lent normalization facto	or K _{MOD}
		Modulation	K_{MOD}	
		BPSK	1	
		QPSK	1/√2	
		16-QAM	1/√10	
		64-QAM	1/√42	
	See, e.g., 802.11-2007 § 17.3.5	5.7		

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	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{cases} N_{SD}^{-1} \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k)\Delta_{F}(t-T_{GI})) \\ N_{ST}^{/2} \\ + p_{n+1} \sum_{k=-N_{ST}^{/2}} P_{k} \exp(j2\pi k\Delta_{F}(t-T_{GI})) \\ k = -N_{ST}^{/2} \end{cases}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

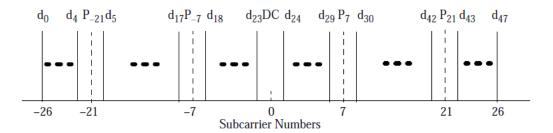


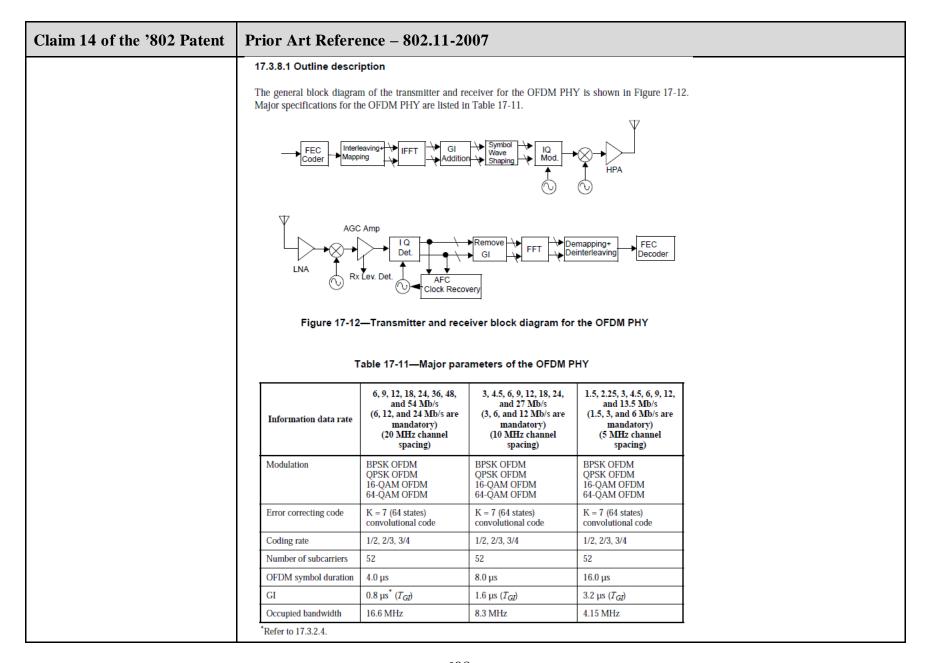
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

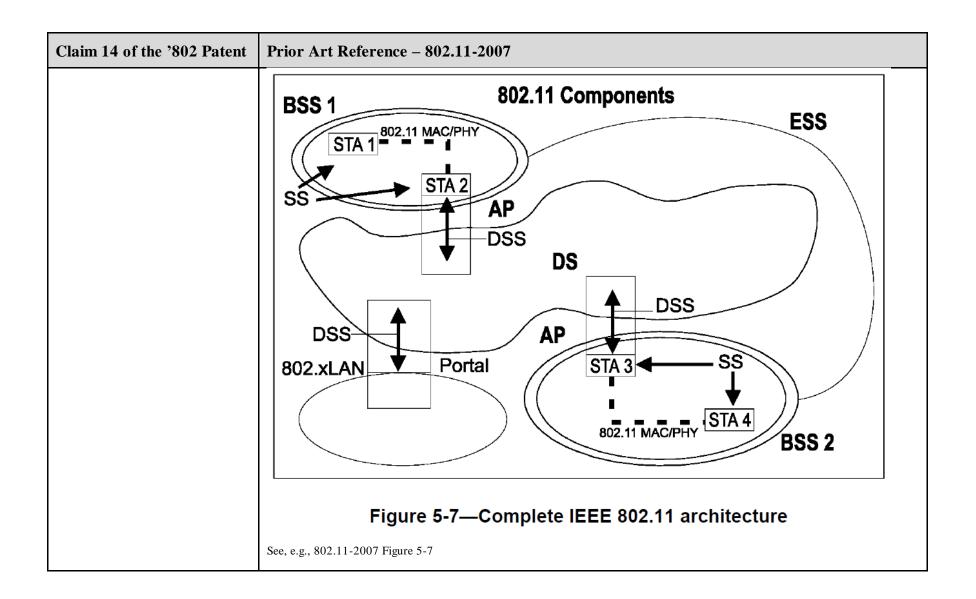
Claim 14 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

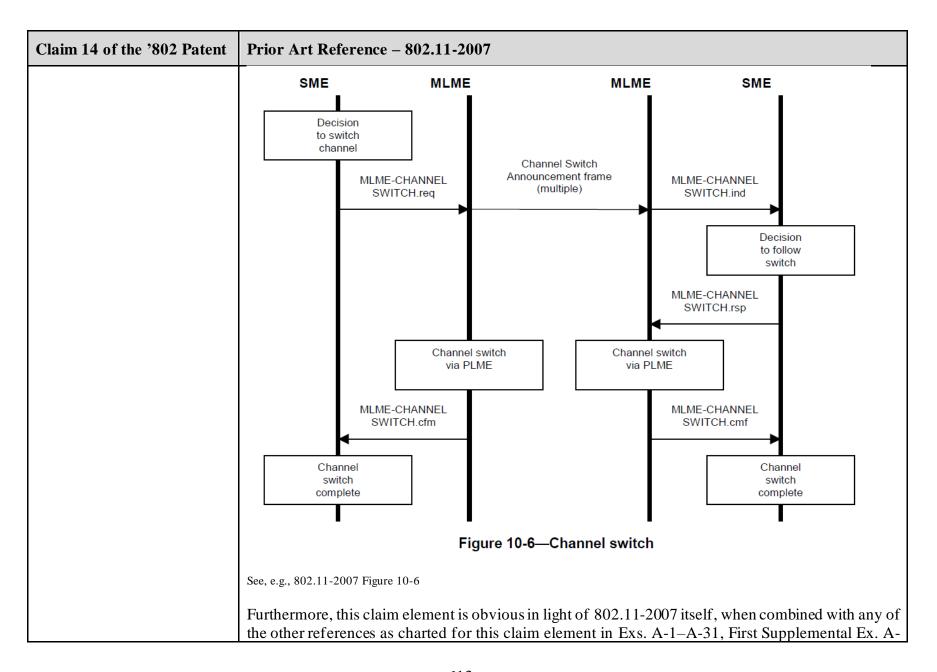


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

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	I.2.2 Transmit power levels						
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5. Table I.4—Transmit power level by regulatory domain						
		Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)		Europe (EIRP)		
		5.15–5.25	40 (2.5 mW/MHz)		200 mW		
		5.25–5.35	200 (12.5 mW/MHz)		200 mW		
		5.470-5.725	_		1 W		
		5.725-5.825	800 (50 mW/MHz)		_		
	Table I.5—U.S. public safety transmit power levels by regulatory domain U.S. public safety (mW) Frequency band					ain	
		(GHz)	20 MHz channels	10 MHz channels	5 MHz channels		
		4.94–4.99 low power	100	50	25		
		4.94–4.99 high power	2000	1000	500		
	See, e.g., 802.11-2007 § 1.2.2						

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	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





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	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
[17.1] A wireless communication system comprising:	To the extent the preamble is limiting, 802.11-2007 discloses "A wireless communication system comprising." See, e.g.:

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,\ 26} = \{1,\ 1,\ -1,\ -1,\ 1,\ 1,\ -1,\ 1,\ 1,\ 1,\ 1,\ 1,\ 1,\ -1,\ 1,\ 1,\ -1,\ 1,\ 1,\ 1,\ 1,\ 1,\ 0,$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[17.2] a baseband digital system for providing a first digital signal comprising a first data to be transmitted and a second digital signal comprising a second data to be transmitted;	802.11-2007 discloses "a baseband digital system for providing a first digital signal comprising a first data to be transmitted and a second digital signal comprising a second data to be transmitted." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies

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	e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts

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	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation
	f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2

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	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

a Rx PLC PD elay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin, aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRXTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

atent Prior Art Re	ference –	802.11-2007
Name	Туре	Description
aRxTxSwitchTime	Integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
аТхRаmpOпTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDela	ny Integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIES) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFacto	or Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation:
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.5 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers, associated
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters					
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)		
	N _{SD} : Number of data subcarriers	48	48	48		
	N_{SP} : Number of pilot subcarriers	4	4	4		
	N_{ST} : Number of subcarriers, total	$52 (N_{SD} + N_{SP})$	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})		
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)		
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$		
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$		
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)		
	$T_{G\vec{I}}$: GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)		
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)		
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)		

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μs (10 × T _{FFT} /4)	16 μ s (10 × T_{FFT} /4)	32 μs (10 × T _{FFT} /4)
	T _{LONG} : Long training sequence duration	8 $\mu s (T_{GIZ} + 2 \times T_{FFT})$	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$
	See, e.g., 802.11-2007 § 17.3.2.3			· · · · · · · · · · · · · · · · · · ·

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(0)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GI}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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Claim 17 of the '802 Patent	Prior Art Reference — 802.11-2007 $w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \end{cases} $ In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters. $T = T_{GT} + T_{FFT}$
	$T_{GUARD} = T_{GI} \qquad T_{FFT}$ $T = T_{GIZ} + 2T_{FFT}$ $T_{GUARD} = T_{GIZ} + 2T_{FFT}$ $T_{GUARD} = T_{GIZ} + 2T_{FFT}$ $T_{T_{IR}} \qquad T_{T_{IR}} \qquad T_{T_{IR}}$ (b) $T_{T_{IR}} \qquad T_{T_{IR}} \qquad T_{T_{I$
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations	
	The following descriptions of the discrete time implementation are informational.	
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes	

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)	
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.	
	$8+8=16\mu\text{s}$ $10\times0.8=8\mu\text{s}$ $2\times0.8+2\times3.2=8.0\mu\text{s}$ $t_1t_2t_3t_4t_5t_6t_7t_8t_9t_{10}\text{GI2}$ T_1 T_2 $GI\mid SIGNAL GI\mid Data 1 GI\mid Data 2$ $Signal Detect, Coarse Freq. Channel and Fine Frequency RATE SERVICE + DATA DATA$	
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize	
	Figure 17-4—OFDM training structure	
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.	

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G.12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD}$			(17-20)
	The normalization factor, K _{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 17-6—Modulation-dependent normalization factor K _{MOD}			
		Modulation	K_{MOD}	
	BPSK 1			
	QPSK 1/√2			
	16-QAM 1/√10			
	64-QAM 1/√42			
	See, e.g., 802.11-2007 § 17.3.5.7			

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007	
	17.3.5.8 Pilot subcarriers	
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.	
	See, e.g., 802.11-2007 § 17.3.5.8	

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{cases} N_{SD}^{-1} \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k)\Delta_{F}(t-T_{GI})) \\ N_{ST}^{/2} \\ + p_{n+1} \sum_{k=-N_{ST}^{/2}} P_{k} \exp(j2\pi k\Delta_{F}(t-T_{GI})) \\ k = -N_{ST}^{/2} \end{cases}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

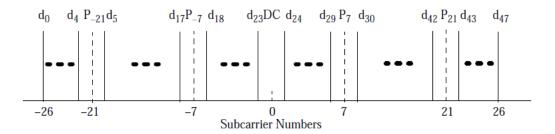


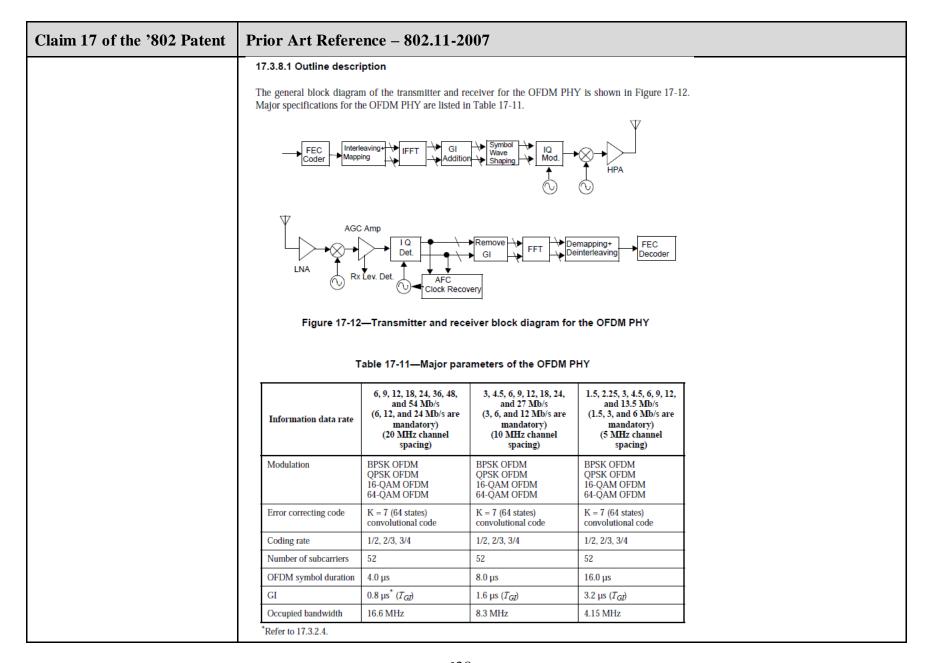
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
 (17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

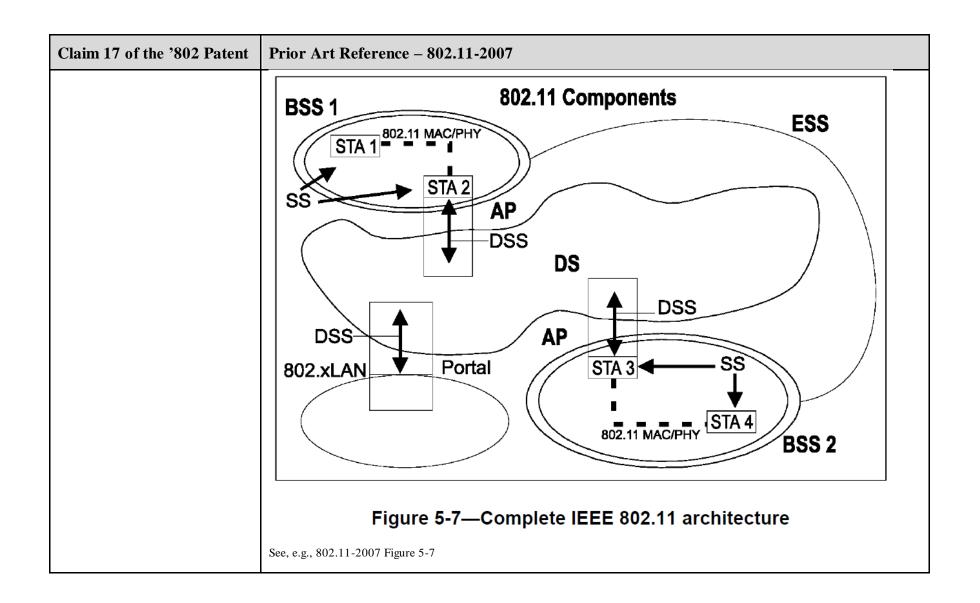
Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

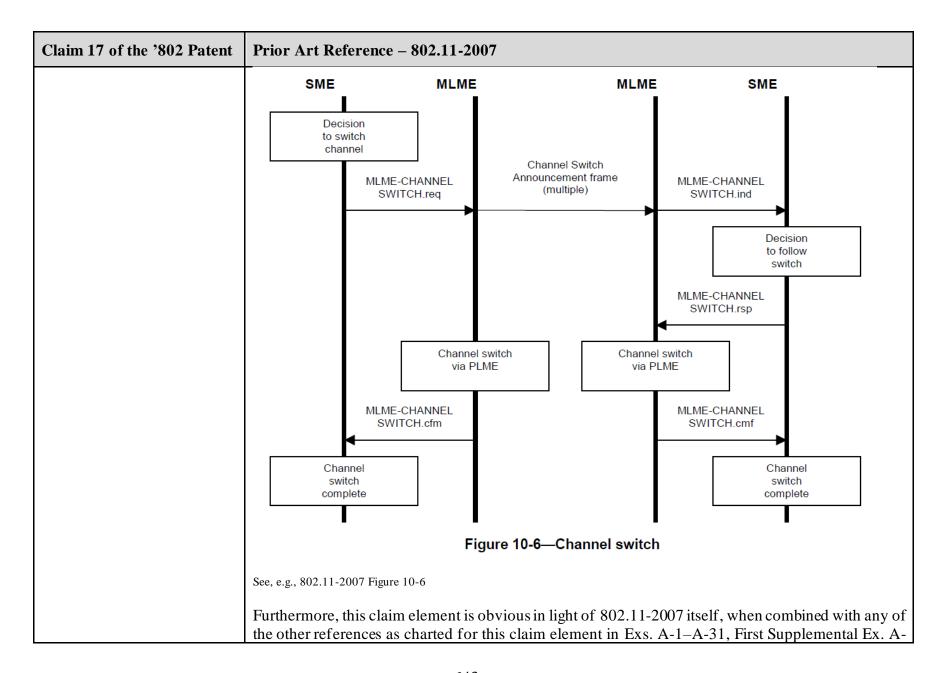


Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007				
	I.2.2 Transmit power levels				
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.				
	Table I.4—Transmit power level by regulatory domain				
	Frequency band (GHz)	(GHz) up to 6 dBi antenna gain) (EIRP)			
	5.15–5.25	40 (2.5 mW/MHz)		200 mW	
	5.25-5.35	200 (12.5 mW/MHz)		200 mW	
	5.470-5.725	_		1 W	
	5.725–5.825	800 (50 mW/MHz)		_	
	(GHz) 5.15–5.25 5.25–5.35 5.470–5.725 5.725–5.825	Frequency band (Maximum output power with up to 6 dBi antenna gain) (EIRP)			
		U.S. pul	olic safety (mW)		
	Frequency band (GHz)	20 MHz	olic safety (mW) 10 MHz channels	5 MHz channels	
		20 MHz	10 MHz	5 MHz	

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
[17.3] a first digital-to-analog converter for receiving the first digital signal and converting the first digital signal into a first analog signal, the first data across a first frequency range;	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "a first digital-to-analog converter for receiving the first digital signal and converting the first digital signal into a first analog signal, the first analog signal carrying the first data across a first frequency range." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs, an address is equivalent to a physical location. This is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium
	c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1 7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,

aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrmraroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Prior Art Refe	rence –	- 802.11-2007
Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (recordering) of the bits according to a rule corresponding to the desired RATE. Refer	Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of <i>NCBPS</i> bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers = 21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details. k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details. l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details. m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details. n) Up-convert the resulting "complex baseband" waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details. An illustration of the transmitted frame and its parts appears in Figure 17-4 (in 17.3.3).		coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. i) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit group, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered to 0 to 47 and mapped hereafter into OFDM subcarriers numbered -26 to -22, -20 to -8, -6 to -1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers -21

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	17.3.2.3 Timing related parameters				
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters				
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	N _{SD} : Number of data subcarriers	48	48	48	
	N_{SP} : Number of pilot subcarriers	4	4	4	
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)	
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$	
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$	
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)	
	$T_{G\vec{I}}$: GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)	
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)	
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	T_{SHORT} : Short training sequence duration	8 μs (10 × T _{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)	
	T _{LONG} : Long training sequence duration	8 µs $(T_{GI2} + 2 \times T_{FFT})$	16 μs $(T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$	
	See, e.g., 802.11-2007 § 17.3.2.3		•	·	

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)^{(i)}} = Re\{r\langle t\rangle \exp\langle j2\pi f_e t\rangle\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GID}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations		
	The following descriptions of the discrete time implementation are informational.		
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes		

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{cov}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G.12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).					
	$d = (I + jQ) \times K_{MOD} $ (17-20)					
	The normalization factor, K _{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.					
	Table 17-6—Modulation-dependent normalization factor K _{MOD}					
	,	Modulation K _{MOD}				
	BPSK 1 QPSK 1/√2					
	16-QAM 1/√10					
	64-QAM 1/√42					
	See, e.g., 802.11-2007 § 17.3.5.7					

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	17.3.5.8 Pilot subcarriers			
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.			
	See, e.g., 802.11-2007 § 17.3.5.8			

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{cases} N_{SD}^{-1} \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k)\Delta_{F}(t-T_{GI})) \\ N_{ST}^{/2} \\ + p_{n+1} \sum_{k=-N_{ST}^{/2}} P_{k} \exp(j2\pi k\Delta_{F}(t-T_{GI})) \\ k = -N_{ST}^{/2} \end{cases}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

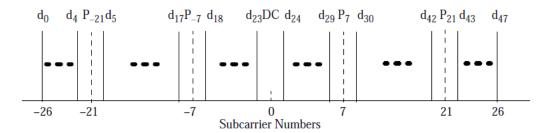


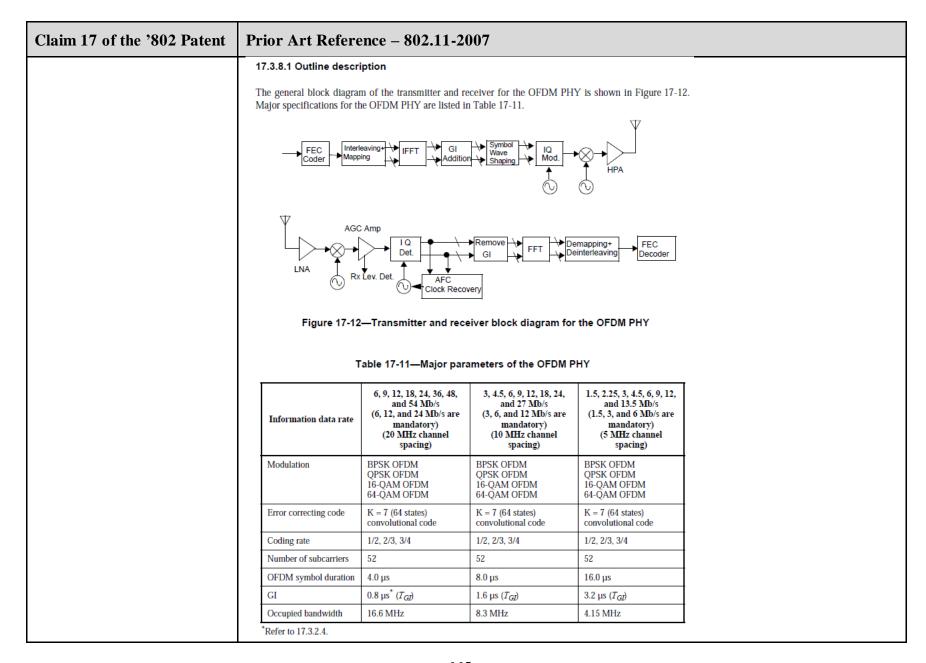
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

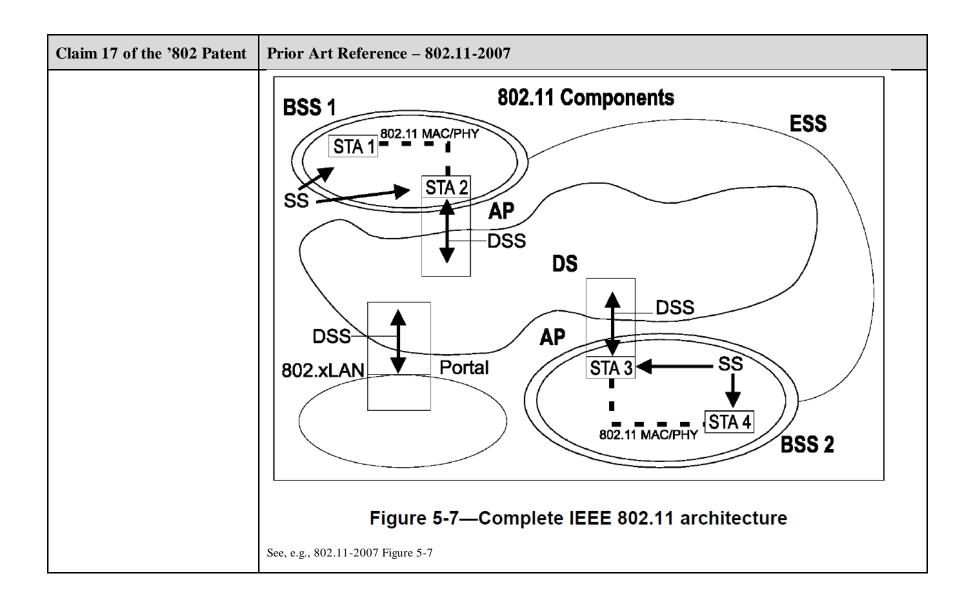
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	See, e.g., 802.11-2007 § 17.3.5.9	

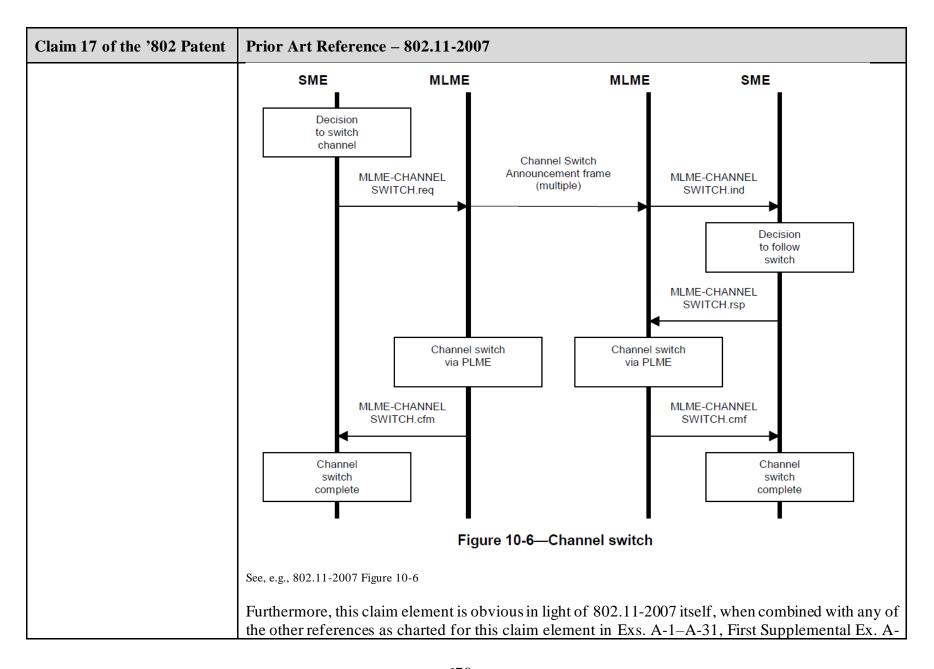


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	See, e.g., 802.11-2007 § 17.3.8.1				
	17.3.8.3.1 Operating frequency range				
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.				
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.				
	See, e.g., 802.11-2007 § 17.3.8.3.1				
	17.3.9.1 Transmit power levels				
	The maximum allowable transmit power by regulatory domain is defined in Annex I.				
	See, e.g., 802.11-2007 § 17.3.9.1				
	17.3.9.6.2 Transmitter spectral flatness				
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.				
	See, e.g., 802.11-2007 § 17.3.9.6.2				

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	I.2.2 Transmit power levels						
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5. Table I.4—Transmit power level by regulatory domain						
	Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)				
	5.15–5.25	40 (2.5 mW/MHz)	200 mW				
	5.25–5.35	200 (12.5 mW/MHz)	200 mW				
	5.470-5.725	_	1 W				
	5.725–5.825	800 (50 mW/MHz)	_				
	Table I.5—U.S. public safety transmit power levels by regulatory doma U.S. public safety (mW)						
	Table I.5—U.S. public s Frequency band (GHz)						
	Frequency band	U.S. public safety (m ² 20 MHz 10 MHz	W) 5 MHz				

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	I.2.3 Transmit spectrum mask				
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.				
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt				
	Typical Signal Spectrum (an example) -40 dBr				
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)				
	Figure I.1—Transmit spectrum mask				
	See, e.g., 802.11-2007 § I.2.3				





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[17.4] a second digital-to-analog converter for receiving the second digital signal and converting the second digital signal into a second analog signal, the second analog signal carrying the second data across a second frequency range;	Prior Art Reference – 802.11-2007 Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "a second digital-to-analog converter for receiving the second digital signal and converting the second digital signal into a second analog signal, the second analog signal carrying the second data across a second frequency range." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly
	f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

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	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.		
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.		
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.		
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.		
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3		
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.		
	See, e.g., 802.11-2007 § 5.2		
	5.2.3 Distribution system (DS) concepts		
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.		
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.		

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	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.			
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.			
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.			
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.			
	See, e.g., 802.11-2007 § 5.2.3			
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.			
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.			
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.			
	See, e.g., 802.11-2007 § 5.3.2			
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.			

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	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.				
	See, e.g., 802.11-2007 § 5.4.4.1 7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20				
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).				
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11				

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,

aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description	
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.	
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.	
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.	
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.	
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrmraroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.	
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).	
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.	

Prior Art Refe	rence –	- 802.11-2007
Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction			
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPS K or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.			
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.			
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.			
	See, e.g., 802.11-2007 § 17.1			
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:			
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and			

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
Claim 17 of the 302 Patent	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subscarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS), Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers anumbered—26 to -22, -20 to -8, -6 to -1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers -2.1,
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related par	ameters		
	Table 17-4 is the list of timing p	parameters associated with	the OFDM PLCP.	
	Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	<i>T_{SYM}</i> : Symbol interval	4 μs $(T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μ s (10 × T_{FFT} /4)
	T _{LONG} : Long training sequence duration	8 µs $(T_{GI2} + 2 \times T_{FFT})$	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(i)} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GIZ}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR}
	$T = T_{GI2} + 2T_{FFT}$ T_{GUARD} $-T_{GI2}$ T_{FFT} T_{FFT} T_{TFT} T_{TR} T_{TR} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations	
	The following descriptions of the discrete time implementation are informational.	
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes	

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{cov}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD} $ (17-20)			(17-20)
	The normalization factor, K _{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 1	7-6—Modulation-depend	dent normalization facto	or K _{MOD}
	,	Modulation	K_{MOD}	
		BPSK	1	
		QPSK	1/√2	
		16-QAM	1/√10	
	64-QAM 1/√42			
	See, e.g., 802.11-2007 § 17.3.5.7			

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{cases} N_{SD}^{-1} \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k)\Delta_{F}(t-T_{GI})) \\ N_{ST}^{/2} \\ + p_{n+1} \sum_{k=-N_{ST}^{/2}} P_{k} \exp(j2\pi k\Delta_{F}(t-T_{GI})) \\ k = -N_{ST}^{/2} \end{cases}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

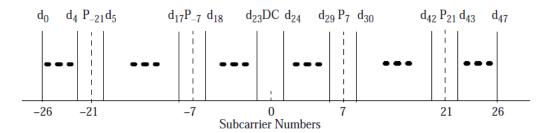


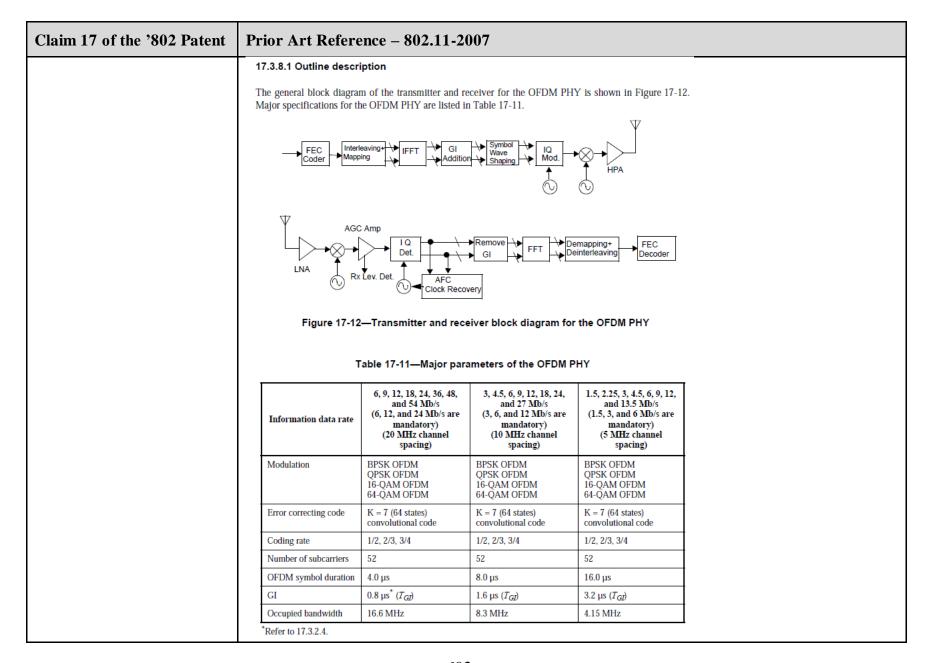
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

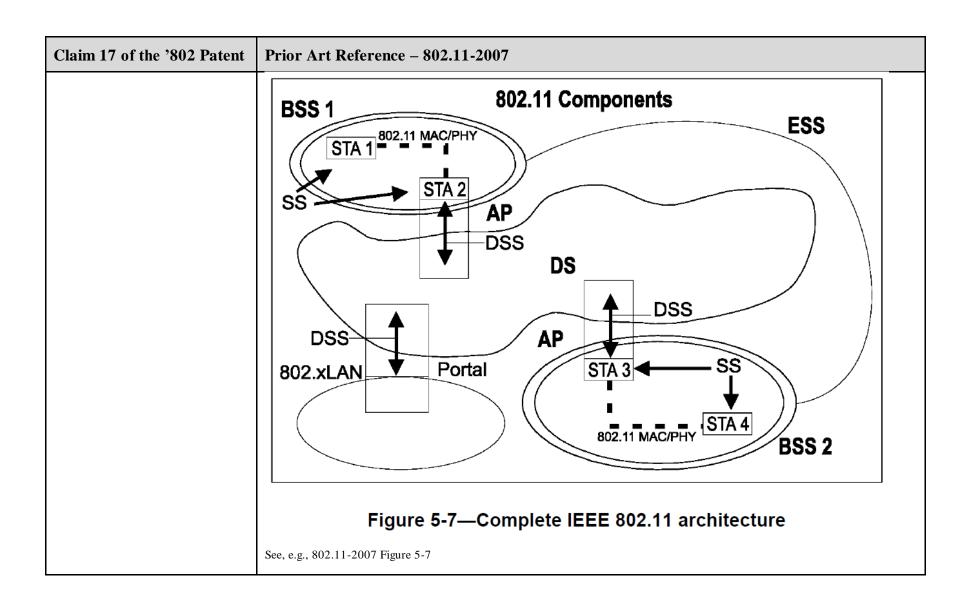
Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

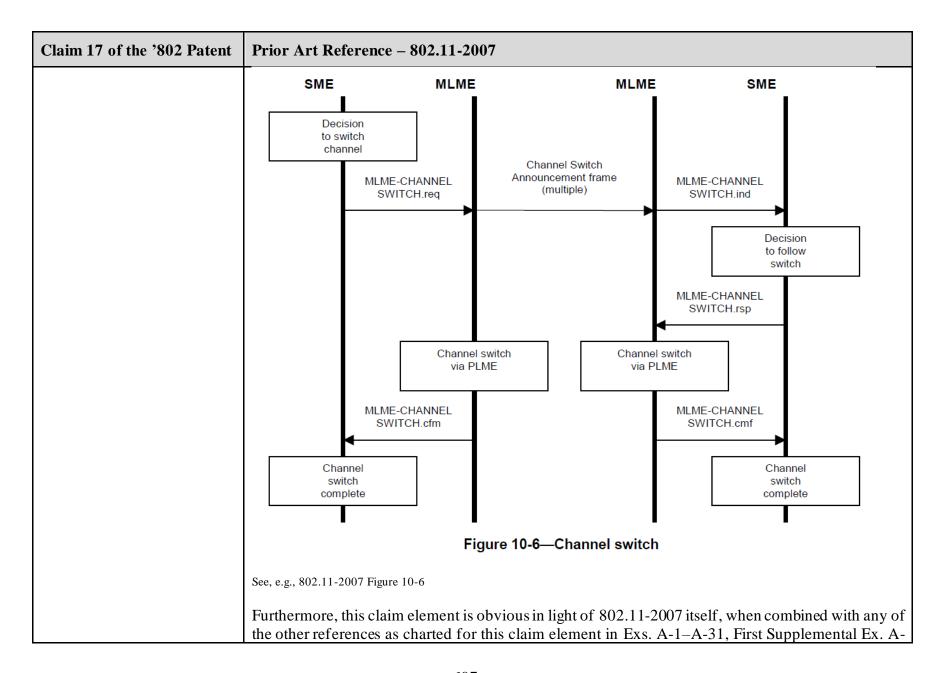


Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007				
	I.2.2 Transmit power levels				
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.				
	Table I.4—Transmit power level by regulatory domain				
	Frequency band (GHz)	(Maximum output p	ower with	Europe (EIRP)	
	5.15-5.25	40 (2.5 mW/MHz)		200 mW	
	5.25-5.35	200 (12.5 mW/MHz)		200 mW	
	5.470-5.725	_		1 W	
	5.725–5.825	800 (50 mW/MHz)		_	
	(GHz) 5.15–5.25 5.25–5.35 5.470–5.725 5.725–5.825	(GHz) up to 6 dBi antenna gain) (mW) (EIRP) 5.15-5.25 40 (2.5 mW/MHz) 200 mW 5.25-5.35 200 (12.5 mW/MHz) 200 mW 5.470-5.725 — 1 W			
		U.S. pul	olic safety (mW)		
	Frequency band (GHz)	20 MHz	olic safety (mW) 10 MHz channels	5 MHz channels	
		20 MHz	10 MHz	5 MHz	

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative
	to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz) Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[17.5] a first up-converter circuit having a first input coupled to receive the first analog signal and a second input coupled to receive a first modulation signal having a	802.11-2007 discloses "a first up-converter circuit having a first input coupled to receive the first analog signal and a second input coupled to receive a first modulation signal having a first RF frequency, wherein the first up-converter outputs a first up-converted analog signal comprising a first up-converted frequency range from the first RF frequency minus one-half the first frequency range to the first RF frequency plus one-half the first frequency range." See, e.g.:
first RF frequency, wherein the first up-converter outputs a first up-converted analog signal comprising a first up-	1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1
converted frequency range from the first RF frequency minus one-half the first frequency range to the first RF frequency plus one-half	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
the first frequency range;	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other)

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime, aPHY-RX-START-Delay, aRxTxTurnaroundTime, aTxPLCPDelay, aRxPLCPDelay, aRxTxSwitchTime,

aTxRampOnTime, aTxRampOffTime,

aTxRFDelay, aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength, aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin, aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Туре	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Prior Art Refe	rence –	- 802.11-2007
Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the
	PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subscarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.5 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.5 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered
	See, e.g., 802.11-2007 § 17.3.2.1

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.3.2.3 Timing related para	ameters		
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	$52 (N_{SD} + N_{SP})$	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 μ s ($T_{GI} + T_{FFT}$)
	$T_{G\vec{I}}$: GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007				
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μ s (10 × T_{FFT} /4)	
	T_{LONG} : Long training sequence duration	8 μ s ($T_{GIZ} + 2 \times T_{FFT}$)	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$	

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)^{(i)}} = Re\{r\langle t\rangle \exp\langle j2\pi f_e t\rangle\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GID}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GI2} + 2T_{FFT}$ T_{GUARD} $-T_{GI2}$ T_{FFT} T_{FFT} T_{TFT} T_{TR} T_{TR} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

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A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 17 of the '802 Patent	Prior Art Reference –	802.11-2007		
	17.3.5.7 Subcarrier mo	odulation mapping		
	RATE requested. The ence (1, 2, 4, or 6) bits and cor- constellation points. The illustrated in Figure 17-10	all be modulated by using BF oded and interleaved binary so the number of the conversion shall be performed, with the input bit, b ₀ , being the resulting (I+jQ) value be the conversion of the conve	serial input data shall be divid rs representing BPSK, QPSK ed according to Gray-coded g the earliest in the stream. T	led into groups of <i>N_{BPSC}</i> , 16-QAM, or 64-QAM constellation mappings, The output values, d, are
	$d = (I + jQ) \times K_{MOD}$			(17-20)
	same average power for	as shown in Figure 17-1. The all mappings. In practical as long as the device.	al implementations, an app	
	described in 17.3.9.6.	7-6—Modulation-depend		n accuracy requirements
	described in 17.3.9.6.	Ü		n accuracy requirements
	described in 17.3.9.6.	7-6—Modulation-depend	lent normalization factor	n accuracy requirements
	described in 17.3.9.6.	7-6—Modulation-depend	lent normalization factor K _{MOD}	n accuracy requirements
	described in 17.3.9.6.	7-6—Modulation-depend Modulation BPSK	lent normalization factor $f K_{MOD}$	n accuracy requirements

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	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

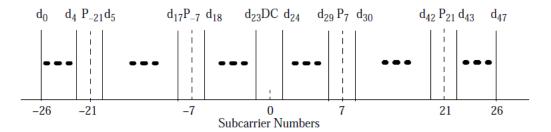


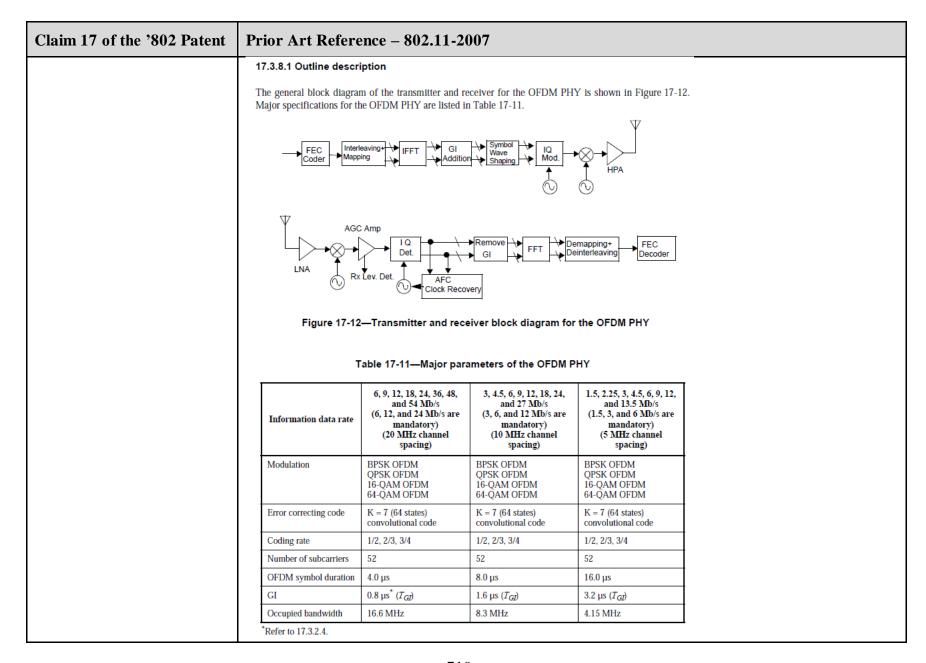
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

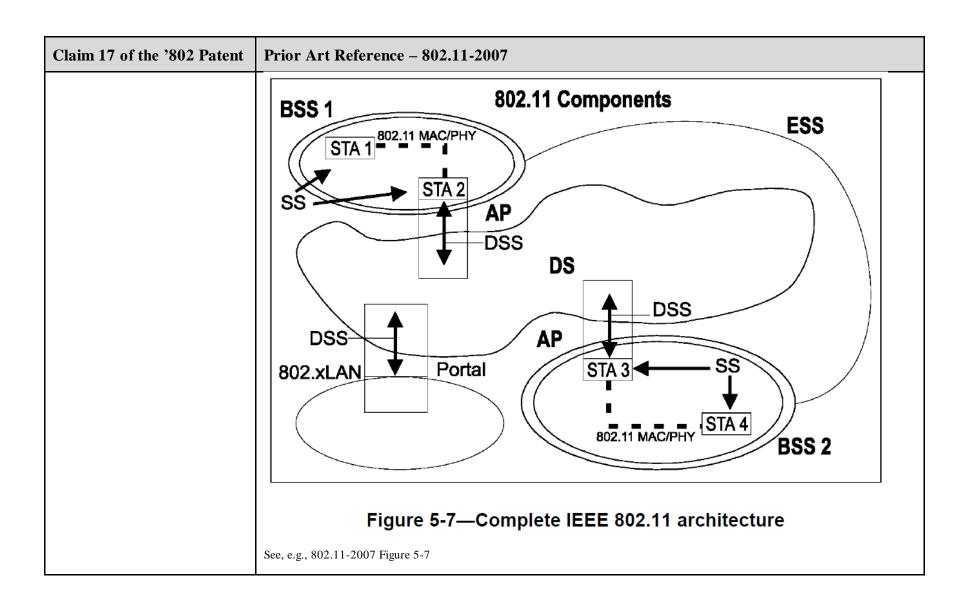
Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

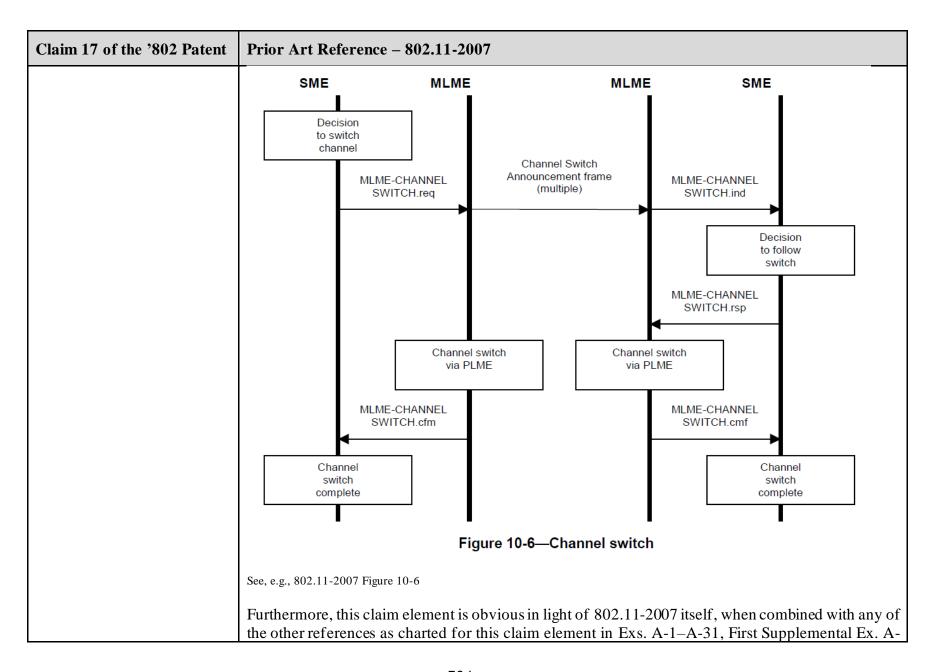


Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007							
	I.2.2 Transmit power levels							
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5. Table I.4—Transmit power level by regulatory domain							
		ncy band Hz)	United (Maximum out) up to 6 dBi ai (mV	put power with ntenna gain)	Europe (EIRP)			
	5.15	-5.25	40 (2.5 m	W/MHz)	200 mW			
	5.25	-5.35	200 (12.5 n	nW/MHz)	200 mW			
	5.470	-5.725	_	-	1 W			
	5.725	-5.825	800 (50 m	W/MHz)	_			
		Table I.5—U.S. public safety transmit power levels by regulatory domain U.S. public safety (mW)						
	Free	quency band	U.S	5. public safety (mV	W)			
	Free	quency band (GHz)	U.S 20 MHz channels	5. public safety (m 10 MHz channels	5 MHz channels			
			20 MHz	10 MHz	5 MHz			

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	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz
	frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz) Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





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	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.
[17.6] a second up-converter	802.11-2007 discloses "a second up-converter circuit having a first input coupled to receive the
circuit having a first input	second analog signal and a second input coupled to receive a second modulation signal having a
coupled to receive the second	second RF frequency, wherein the second up-converter outputs a second up-converted analog signal
analog signal and a second	comprising a second up-converted frequency range from the second RF frequency minus one-half the
input coupled to receive a	second frequency range to the second RF frequency plus one-half the second frequency range, and
second modulation signal	wherein frequency difference between the first RF frequency and the second RF frequency is greater
having a second RF	than the sum of one-half the first frequency range and one-half the second frequency range." See,
frequency, wherein the second	e.g.:
up-converter outputs a second	
up-converted analog signal	1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY)
comprising a second up-	specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.
converted frequency range	
from the second RF frequency	See, e.g., 802.11-2007 § 1.1
minus one-half the second	5.1.1 How WLAN systems are different
frequency range to the second	Wireless networks have fundamental characteristics that make them significantly different from traditional
RF frequency plus one-half	wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio
the second frequency range,	regulations.
and wherein frequency	
difference between the first	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of
RF frequency and the second	wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination,
RF frequency is greater than	but not (in general) a fixed location.
the sum of one-half the first	5.1.1.2 Media impact on design and performance
frequency range and one-half	The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
the second frequency range;	NATE of the state
and	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames
	b) Are unprotected from other signals that may be sharing the medium

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2

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	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration
	e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.

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	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrmraroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receiv to Transmit.
aTxRampOnTime	Integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifler off.
aTxRFDelay	Integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-FXEND.indication primitive (for response after SIFS) or PHY-FCCA.Indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTIme. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[(PPDUblits/PSDUbits)-1) × 10 ³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDUrationFactor × 8 × N) / 10 ³) + (8 × N) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the
	TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of $R = 1/2$, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (RBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM symbol. In eac
	See, e.g., 802.11-2007 § 17.3.2.1

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007 17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP.						
	Table 17-4—Timing-related parameters						
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)			
	N _{SD} : Number of data subcarriers	48	48	48			
	N_{SP} : Number of pilot subcarriers	4	4	4			
	N_{ST} : Number of subcarriers, total	$52 (N_{SD} + N_{SP})$	52 $(N_{SD} + N_{SP})$	$52 (N_{SD} + N_{SP})$			
	Δ_F : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)			
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs (1/ Δ_F)			
	$T_{PREAMBLE}$: PLCP preamble duration	$16 \mu s (T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$			
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 $\mu s (T_{GI} + T_{FFT})$			
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)			
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)			
	T_{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s (T_{GI} + T_{FFT})	16 $\mu s (T_{GI} + T_{FFT})$			

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)	
	T _{LONG} : Long training sequence duration	8 μ s (T_{GI2} + 2 \times T_{FFT})	16 μs $(T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)	

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	17.3.2.4 Mathematical conventions in the signal descriptions	
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:	
	$r_{(RF)^{(i)}} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1)	
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency	
	The transmitted baseband signal is composed of contributions from several OFDM symbols.	
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$	
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.	
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.	
	$N_{ST}/2$	
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)	
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GIZ}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.	

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations		
	The following descriptions of the discrete time implementation are informational.		
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes		

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0,80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12}))$$
 (17-9)

where

$$T_{G.12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	The normalization factor, K _{MOD} , depends on the base modulate that the modulation type can be different from the start to the e			
	The normalization factor, K _{MOD} , depends on the base modulated that the modulation type can be different from the start to the effrom SIGNAL to DATA, as shown in Figure 17-1. The purpose same average power for all mappings. In practical imple normalization factor can be used, as long as the device conform described in 17.3.9.6.	end of the transmission, as the signal changes e of the normalization factor is to achieve the ementations, an approximate value of the		
	that the modulation type can be different from the start to the e from SIGNAL to DATA, as shown in Figure 17-1. The purpose same average power for all mappings. In practical imple normalization factor can be used, as long as the device conform	end of the transmission, as the signal changes e of the normalization factor is to achieve the ementations, an approximate value of the as with the modulation accuracy requirements		
	that the modulation type can be different from the start to the e from SIGNAL to DATA, as shown in Figure 17-1. The purpose same average power for all mappings. In practical imple normalization factor can be used, as long as the device conform described in 17.3.9.6.	end of the transmission, as the signal changes e of the normalization factor is to achieve the ementations, an approximate value of the as with the modulation accuracy requirements		
	that the modulation type can be different from the start to the e from SIGNAL to DATA, as shown in Figure 17-1. The purpose same average power for all mappings. In practical imple normalization factor can be used, as long as the device conform described in 17.3.9.6. Table 17-6—Modulation-dependent normalization.	end of the transmission, as the signal changes e of the normalization factor is to achieve the ementations, an approximate value of the as with the modulation accuracy requirements rmalization factor K _{MOD}		
	that the modulation type can be different from the start to the e from SIGNAL to DATA, as shown in Figure 17-1. The purpose same average power for all mappings. In practical imple normalization factor can be used, as long as the device conform described in 17.3.9.6. Table 17-6—Modulation-dependent normalization	end of the transmission, as the signal changes e of the normalization factor is to achieve the ementations, an approximate value of the as with the modulation accuracy requirements		
	that the modulation type can be different from the start to the e from SIGNAL to DATA, as shown in Figure 17-1. The purpose same average power for all mappings. In practical imple normalization factor can be used, as long as the device conform described in 17.3.9.6. Table 17-6—Modulation-dependent normalization BPSK	end of the transmission, as the signal changes e of the normalization factor is to achieve the ementations, an approximate value of the as with the modulation accuracy requirements		

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007	
	17.3.5.8 Pilot subcarriers	
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.	
	See, e.g., 802.11-2007 § 17.3.5.8	

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA} n(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

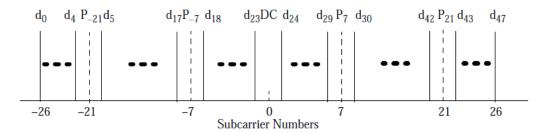


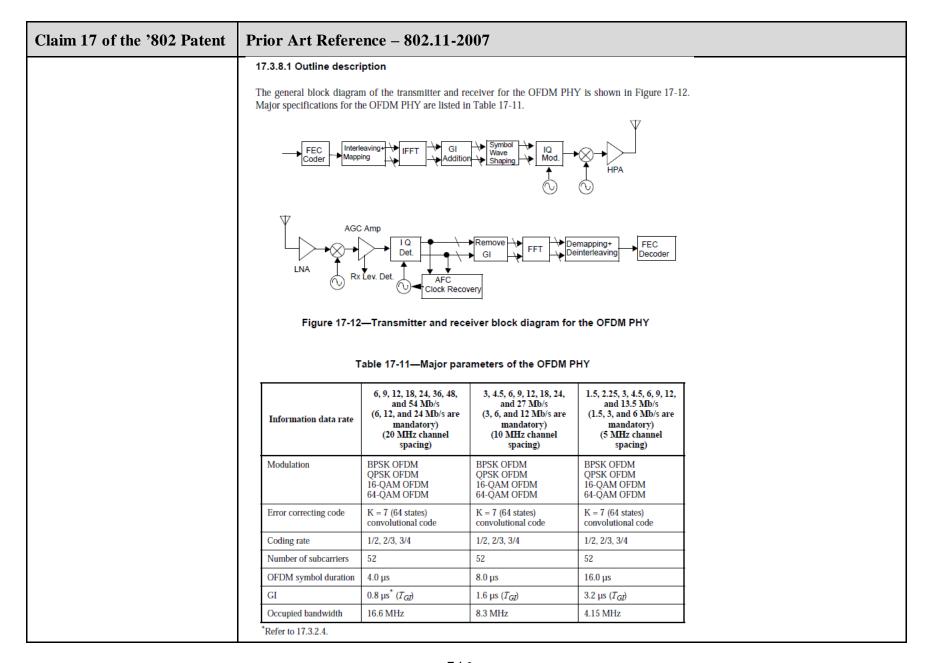
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
 (17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

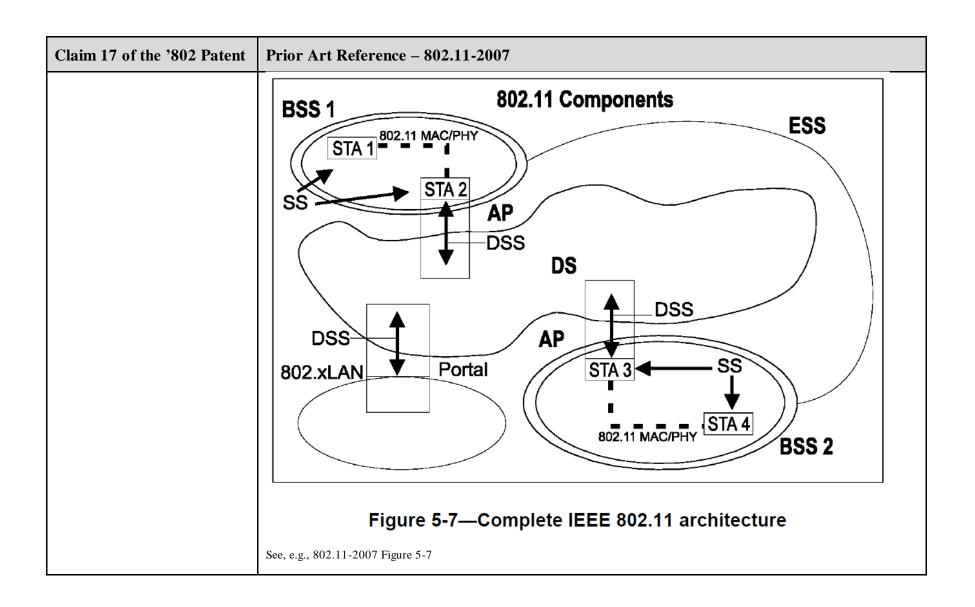
Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007	
	See, e.g., 802.11-2007 § 17.3.5.9	

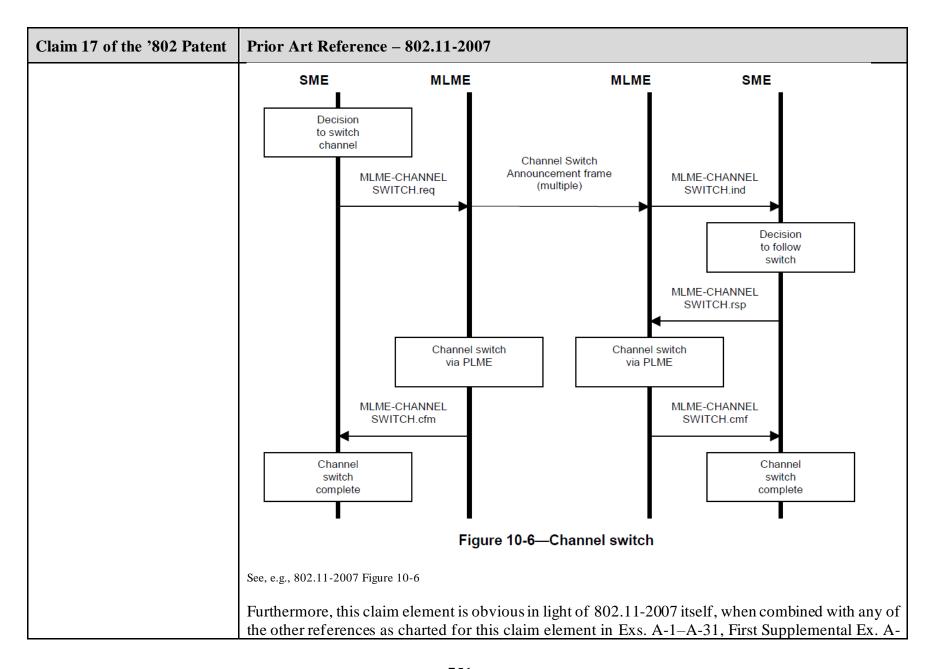


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

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	I.2.2 Transmit power levels					
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.					
		Table I.4—Tran	smit power lev	el by regulator	y domain	
		Frequency band (Maximum output power with Europe (GHz) up to 6 dBi antenna gain) (EIRP) (mW)				
		5.15-5.25	40 (2.5 m	W/MHz)	200 mW	٦
		5.25-5.35	200 (12.5 1	mW/MHz)	200 mW	
		5.470-5.725	_		1 W	
		5.725–5.825	800 (50 n	nW/MHz)	_	
	Table I.5—U.S. public safety transmit power levels by regulatory domain U.S. public safety (mW) Frequency band				ain	
		(GHz)	20 MHz channels	10 MHz channels	5 MHz channels	
		4.94–4.99 low power	100	50	25	
		4.94–4.99 high power 2000 1000 500				
	See, e.g., 802.11-2007 § I.2.2					

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	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





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[17.7] a power amplifier coupled to receive the first and second up-converted analog signals, wherein the bandwidth of the power amplifier is greater than the difference between a lowest frequency in the first up-converted frequency range and a highest frequency in the second up-converted frequency range.	Prior Art Reference – 802.11-2007 Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "a power amplifier coupled to receive the first and second up-converted analog signals, wherein the bandwidth of the power amplifier is greater than the difference between a lowest frequency in the first up-converted frequency range and a highest frequency in the second up-converted frequency range." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is

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	built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used

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	to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime, aPHY-RX-START-Delay, aRxTxTurnaroundTime, aTxPLCPDelay, aRxPLCPDelay, aRxTxSwitchTime, aTxRampOnTime, aTxRampOffTime, aTxRFDelay, aRxRFDelay, aAirPropagationTime, aMACProcessingDelay, aPreambleLength, aPLCPHeaderLength,

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

aMPDUDurationFactor, aMPDUMaxLength, aCWmin, aCWmax

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: atxPLCPDelay + arxTxSwitchTime + atxRampOnTime + atxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

Prior Art Refe	rence –	- 802.11-2007
Name	Type	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

prepending a Gl as described subsequently for data transmission with BPSK-OPDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OPDM symbol (NDBPS), the coding rate (R), the number of bits in each OPDM subcarrier (NBPSC), and the number of coded bits per OPDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nozero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1.2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (crordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers, associated with enetter frequency, is omitted and filled with zero to Jn. 3.5 for details. j) Divide the	Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
See, e.g., 802.11-2007 § 17.3.2.1		prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. C) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.1 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers as

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007				
	17.3.2.3 Timing related para	ameters			
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP.				
	1	Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	N _{SD} : Number of data subcarriers	48	48	48	
	N_{SP} : Number of pilot subcarriers	4	4	4	
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)	
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$	
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μ s ($T_{SHORT} + T_{LONG}$)	
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 μ s ($T_{GI} + T_{FFT}$)	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 μ s ($T_{GI} + T_{FFT}$)	
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)	
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (T _{FFT} /2)	
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)
	T _{LONG} : Long training sequence duration	8 μ s ($T_{GI2} + 2 \times T_{FFT}$)	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)^{(i)}} = Re\{r\langle t\rangle \exp(j2\pi f_c t)\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp\left(j2\pi k \Delta_f\right) (t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GID}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period
	See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{m}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G.12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 17 of the '802 Patent	Prior Art Reference –	- 802.11-2007		
	17.3.5.7 Subcarrier mo	odulation mapping		
	RATE requested. The end (1, 2, 4, or 6) bits and constellation points. The illustrated in Figure 17-10	nall be modulated by using BF coded and interleaved binary s nverted into complex number conversion shall be performed, with the input bit, b ₀ , being the resulting (I+jQ) value be	erial input data shall be diving the representing BPSK, QPSI and according to Gray-coded gothe earliest in the stream.	ded into groups of N_{BPSC} K, 16-QAM, or 64-QAM I constellation mappings, The output values, d, are
	$\mathbf{d} = (\mathbf{I} + \mathbf{j}\mathbf{Q}) \times \mathbf{K}_{\mathbf{MOD}}$			(17-20)
	from SIGNAL to DATA, same average power fo normalization factor can be	can be different from the start as shown in Figure 17-1. The or all mappings. In practica be used, as long as the device of	e purpose of the normalizational implementations, an ap	on factor is to achieve the
	described in 17.3.9.6.			
		17-6—Modulation-depend		on accuracy requirements
		17-6—Modulation-depend		on accuracy requirements
			lent normalization facto	on accuracy requirements
		Modulation	lent normalization facto $ m K_{MOD}$	on accuracy requirements
		Modulation BPSK	lent normalization facto K _{MOD}	on accuracy requirements

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

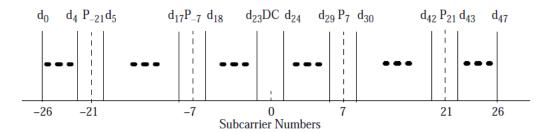


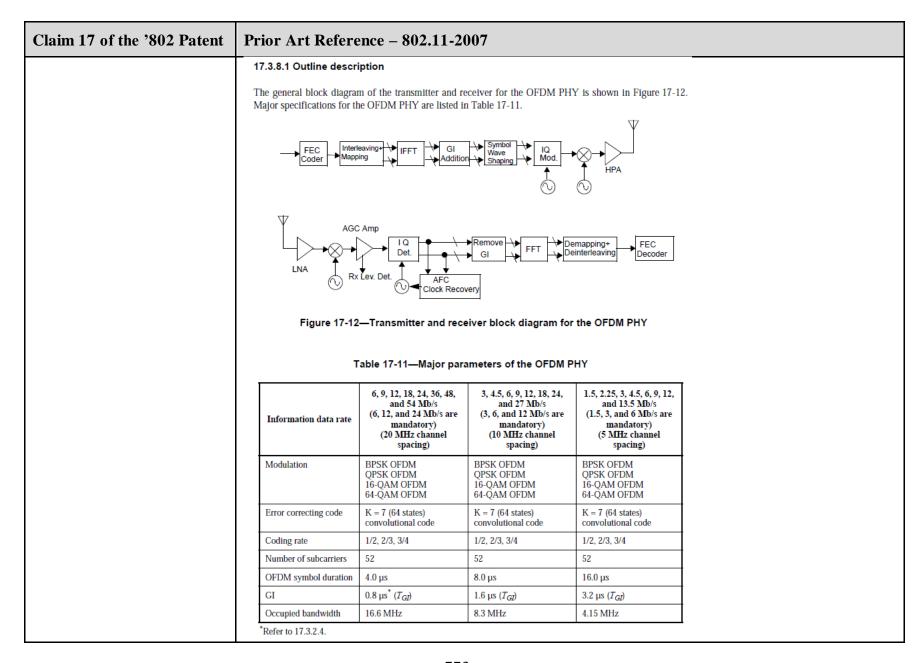
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
 (17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

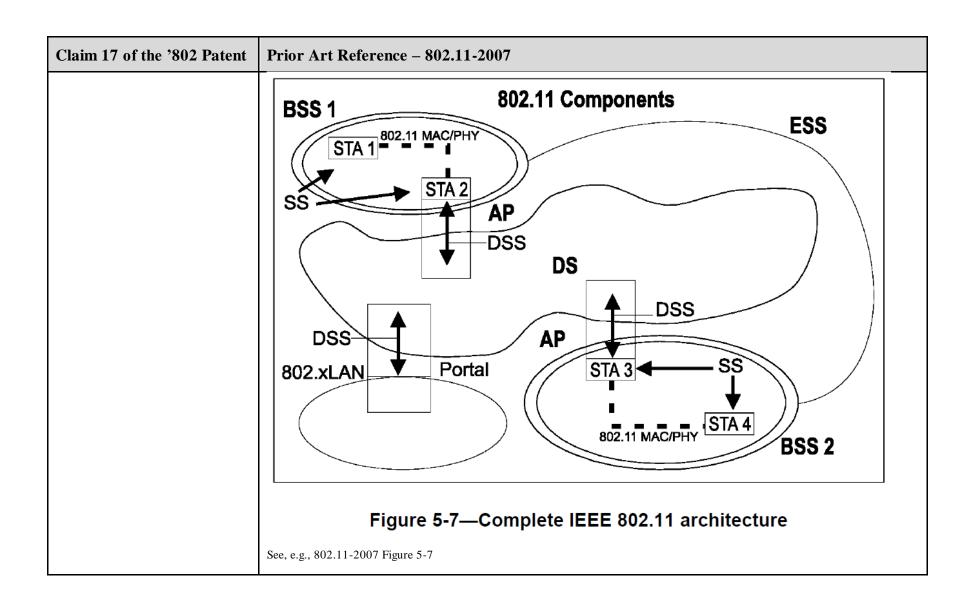
Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

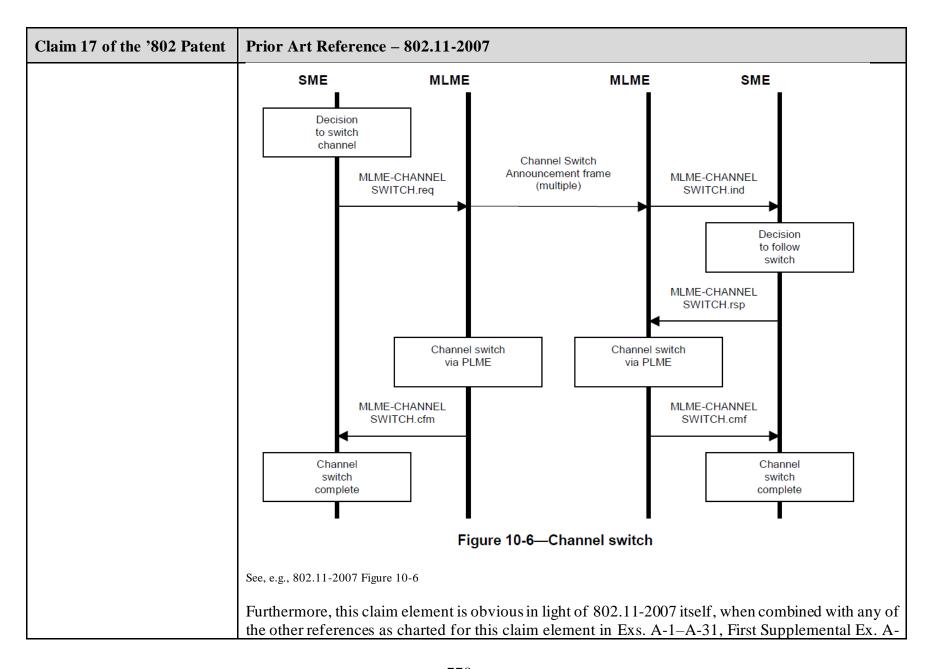


Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-20	007		
	I.2.2 Transmit power levels			
	The maximum allowable output pow maximum allowable output power by Table I.5.			
	Table I.4—Tr	ansmit power level by regulator	y domain	
	Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)	
	5.15–5.25	40 (2.5 mW/MHz)	200 mW	
	5.25–5.35	200 (12.5 mW/MHz)	200 mW	
	5.470-5.725	_	1 W	
	5.725–5.825	800 (50 mW/MHz)	_	
		,		
		safety transmit power levels by U.S. public safety (m)		
	Table I.5—U.S. public s Frequency band (GHz)			
	Frequency band	U.S. public safety (m ² 20 MHz 10 MHz	W) 5 MHz	

Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz
	frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz) Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 17 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.

Claim 21 of the '802 Patent	Prior Art Reference – 802.11-2007
[21.1] The communication system of claim 17	802.11-2007 discloses all the elements of claim 17 for all the reasons provided above.
[21.2] wherein the first data of the first digital signal is encoded using a first wireless protocol and the first data of the second digital signal is	802.11-2007 discloses "wherein the first data of the first digital signal is encoded using a first wireless protocol and the first data of the second digital signal is encoded using a second wireless protocol." See, e.g.: 1.1 Scope
the second digital signal is encoded using a second wireless protocol.	The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different
	Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network framesb) Are unprotected from other signals that may be sharing the medium

Claim 21 of the '802 Patent	Prior Art Reference – 802.11-2007
	c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2

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	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.

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	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

> aSlotTime, aSIFSTime, aCCATime, aPHY-RX-START-Delay,

> aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay, aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin, aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrmraroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

	-	
Name	Туре	Description
aRxTxSwitchTime	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the
	PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NOBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. b) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. b) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers num

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	17.3.2.3 Timing related para	ameters		
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μ s ($T_{SHORT} + T_{LONG}$)
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 μ s ($T_{GI} + T_{FFT}$)	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 $\mu s (10 \times T_{FFT}/4)$	32 μs (10 × T _{FFT} /4)
	T_{LONG} : Long training sequence duration	8 µs $(T_{GI2} + 2 \times T_{FFT})$	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 μ s ($T_{GI2} + 2 \times T_{FFT}$)

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)^{(i)}} = Re\{r\langle t\rangle \exp(j2\pi f_c t)\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GI}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations	
	The following descriptions of the discrete time implementation are informational.	
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes	

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)	
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.	
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2	
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH	
	Figure 17-4—OFDM training structure	
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.	

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD} $ (17-20)			(17-20)
	that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 17-6—Modulation-dependent normalization factor K _{MOD}		or K _{MOD}	
		Modulation	K_{MOD}	
		BPSK	1	
		QPSK	1/√2	
		 		
		16-QAM	1/√10	

Claim 21 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA} n(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

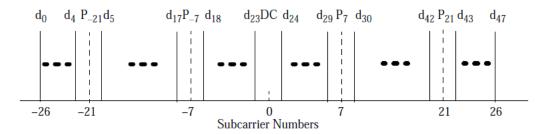


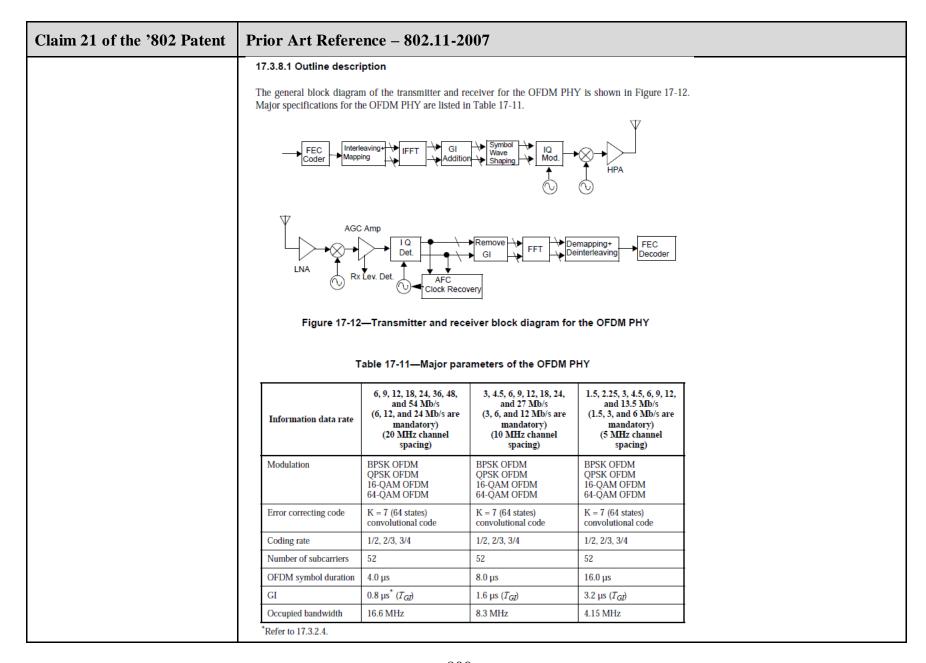
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

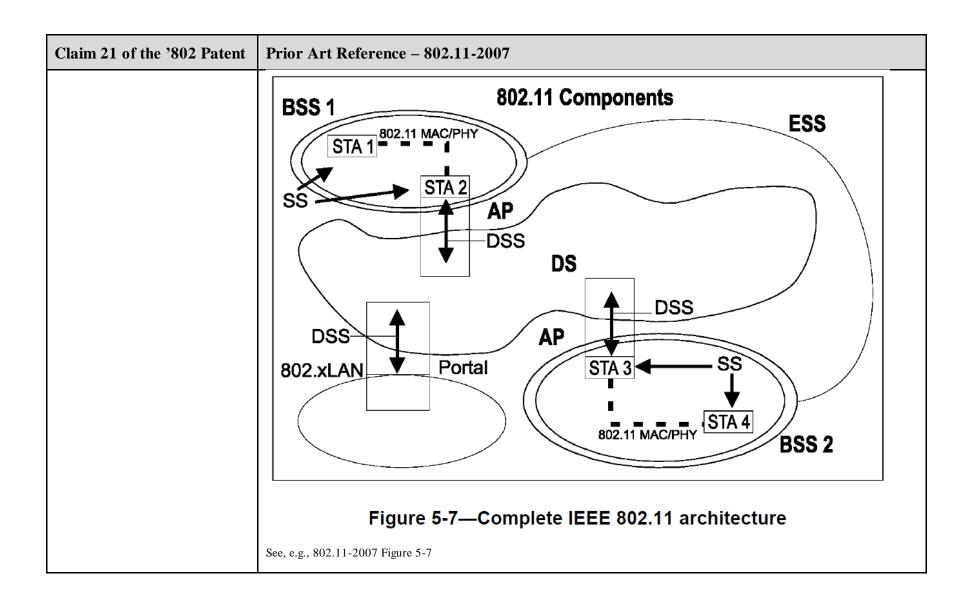
Claim 21 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

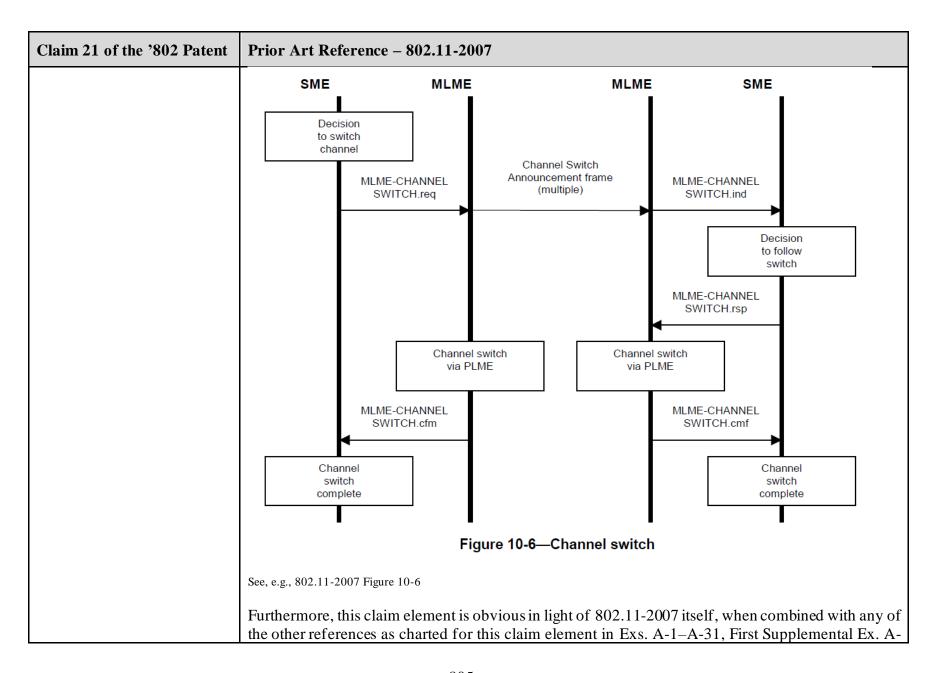


Claim 21 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 21 of the '802 Patent	Prior Art Reference – 802.11-2007				
	I.2.2 Transmit power levels				
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5. Table I.4—Transmit power level by regulatory domain				
	Frequency band (GHz)	United States nd (Maximum output power with up to 6 dBi antenna gain) (mW)		Europe (EIRP)	
	5.15–5.25	40 (2.5 mW/MHz)		200 mW	1
	5.25–5.35	200 (12.5 mW/MHz)		200 mW	
	5.470-5.725	_		1 W	
	5.725–5.825	800 (50 mW/MHz)		_	
	5.15-5.25 5.25-5.35 5.470-5.725	(m) 40 (2.5 m) 200 (12.5 m) — 800 (50 m)	W) W/MHz) nW/MHz) - W/MHz)	200 mW 200 mW 1 W	n
			S. public safety (m		
			Public salety (III	,	
	Frequency band (GHz)	20 MHz channels	10 MHz channels	5 MHz channels	
		20 MHz	10 MHz	5 MHz	

Claim 21 of the '802 Patent	Prior Art Reference – 802.11-2007		
	I.2.3 Transmit spectrum mask		
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.		
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt		
	Typical Signal Spectrum (an example) -40 dBr		
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)		
	Figure I.1—Transmit spectrum mask		
	See, e.g., 802.11-2007 § I.2.3		





Claim 21 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
[22.1] The communication system of claim 17	802.11-2007 discloses all the elements of claim 17 for all the reasons provided above.
[22.2] wherein the second data corresponds to the first data and wherein the power amplifier outputs a third upconverted signal comprising the up-converted first analog signal and the up-converted second analog signal.	802.11-2007 discloses "wherein the second data corresponds to the first data and wherein the power amplifier outputs a third up-converted signal comprising the up-converted first analog signal and the up-converted second analog signal." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance
	The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime, aPHY-RX-START-Delay, aRxTxTurnaroundTime, aTxPLCPDelay, aRxPLCPDelay, aRxTxSwitchTime, aTxRampOnTime, aTxRampOffTime, aTxRFDelay, aRxRFDelay, aAirPropagationTime, aMACProcessingDelay, aPreambleLength, aPLCPHeaderLength, aMPDUDurationFactor, aMPDUMaxLength, aCWmin, aCWmax

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

N	T	December
Name aRxTxSwitchTime	Type	Description The nominal time (in microseconds) that the PMD takes to switch from Receive
aTxRampOnTime	integer	to Transmit. The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (In microseconds) between the Issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-TXEND.indication primitive (for response after SIFS) or PHY-CCA.Indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[(PPDUblits/PSDUbits)-1) × 10 ³]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets)) / 10 ³ + (8 × PSDUoctets)) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10 ³) + (8 × N) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subscarrier (RDBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers anumbered
	See, e.g., 802.11-2007 § 17.3.2.1

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP.			
	Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 µs $(1/\Delta_F)$
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs ($T_{SHORT} + T_{LONG}$)
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 μ s ($T_{GI} + T_{FFT}$)	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 μ s ($T_{GI} + T_{FFT}$)
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)
	T_{LONG} : Long training sequence duration	8 μ s ($T_{GIZ} + 2 \times T_{FFT}$)	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(t)} = Re\{r\langle t\rangle \exp(j2\pi f_c t)\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GID}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR}
	$T = T_{GI2} + 2T_{FFT}$ T_{GUARD} $= T_{GI2}$ T_{FFT} T_{FFT} T_{TR} T_{TR} T_{TR} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null 0
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$d = (I + jQ) \times K_{MOD} $ (17-20)			
	The normalization factor, K_{MOD} , depends on the base modulation mode, as prescribed in Table 17-6. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 17-6—Modulation-dependent normalization factor K _{MOD}			
	l	Modulation	K _{MOD}	
	İ	BPSK	1	7
		QPSK	1/√2	
		16-QAM	1/√10	
		64-QAM	1/√42	
	See, e.g., 802.11-2007 § 17.3.5.	.7		

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007	
	17.3.5.8 Pilot subcarriers	
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.	
	See, e.g., 802.11-2007 § 17.3.5.8	

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

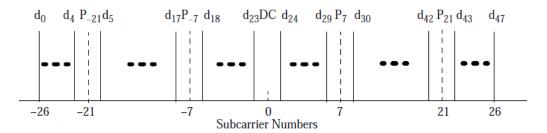


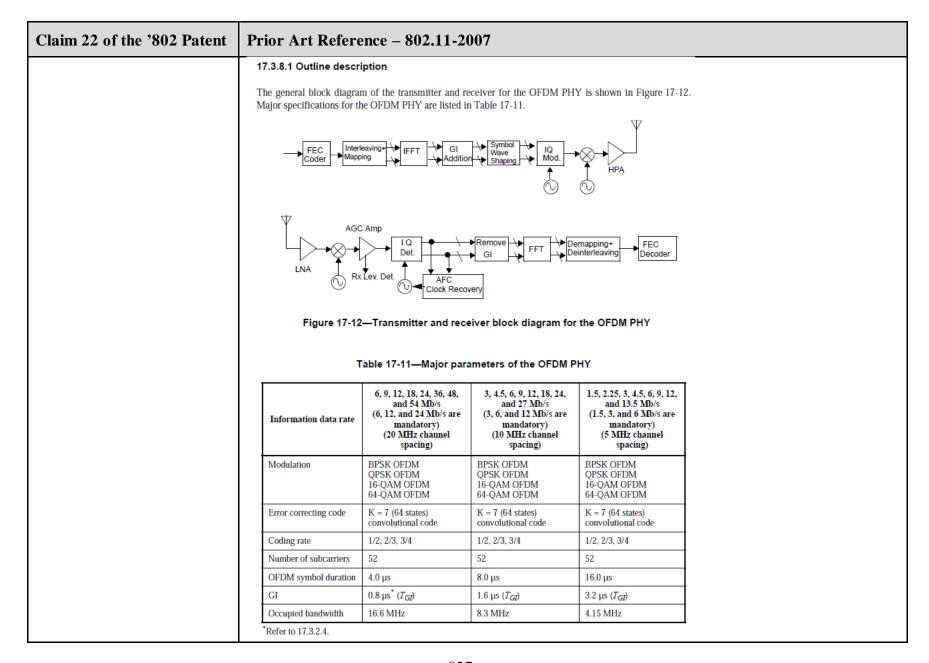
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

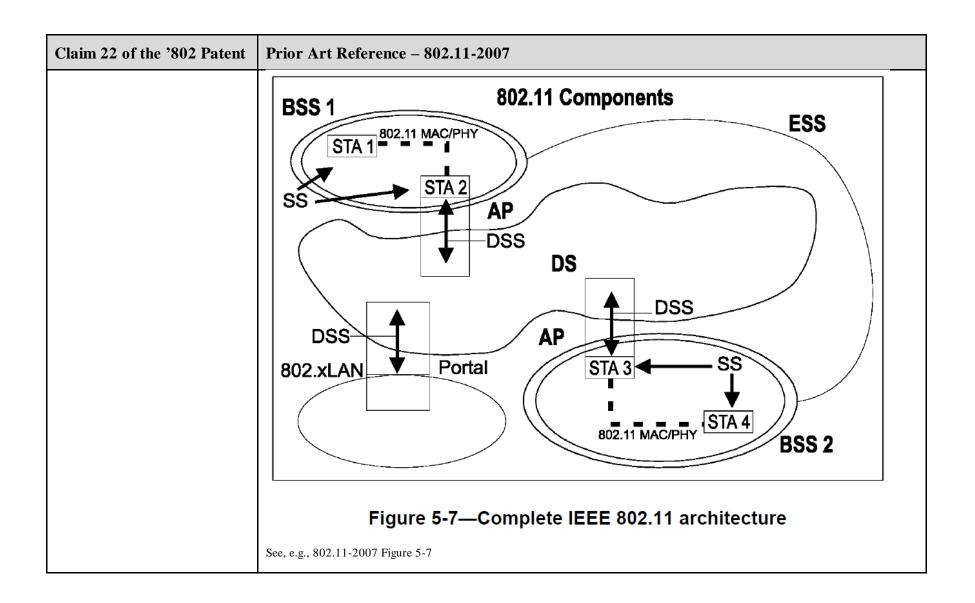
Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007	
	See, e.g., 802.11-2007 § 17.3.5.9	

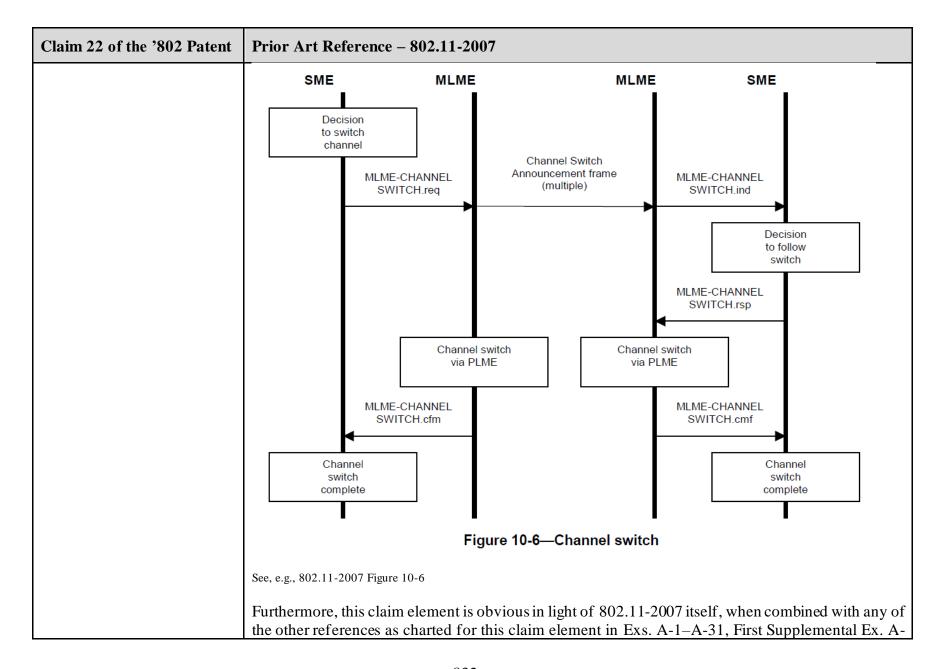


Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007 I.2.2 Transmit power levels The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5. Table I.4—Transmit power level by regulatory domain			
	Frequency band (GHz)	(Maximum ou up to 6 dBi a	l States tput power with untenna gain) W)	Europe (EIRP)
	5.15–5.25	40 (2.5 m	nW/MHz)	200 mW
	5.25–5.35	200 (12.5	mW/MHz)	200 mW
	5.470-5.725	-	_	1 W
	5.725-5.825	800 (50 n	nW/MHz)	_
	5.25–5.35 5.470–5.725	200 (12.5 - 800 (50 n	mW/MHz) — nW/MHz)	200 mW 1 W —
		U.	S. public safety (m	W)
	Frequency band (GHz)	20 MHz channels	10 MHz channels	5 MHz channels
			50	2.5
	4.94–4.99 low power	100	50	25

Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 22 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
[23.1] The communication system of claim 17	802.11-2007 discloses all the elements of claim 17 for all the reasons provided above.
[23.2] wherein first and second data to be transmitted comprise a plurality of OFDM symbols, wherein a first symbol is transmitted during a first time slot across the first up-converted frequency range and a second symbol is transmitted during the first time slot across the second up-converted frequency range, and wherein a third symbol is transmitted during a second time slot across the first up-converted frequency range and a fourth symbol is transmitted during the second time slot across a second up-converted frequency range.	802.11-2007 discloses "wherein first and second data to be transmitted comprise a plurality of OFDM symbols, wherein a first symbol is transmitted during a first time slot across the first up-converted frequency range and a second symbol is transmitted during the first time slot across the second up-converted frequency range, and wherein a third symbol is transmitted during a second time slot across the first up-converted frequency range and a fourth symbol is transmitted during the second time slot across a second up-converted frequency range." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation
	f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007	
	See, e.g., 802.11-2007 § 10.3.11	

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRXTXTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxRFDelay,
aAirPropagationTime,

aPreambleLength, aPLCPHeaderLength, aMPDUDurationFactor,

aMACProcessingDelay,

aMPDUDurationFactor

aCWmin, aCWmax)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrurnaroundTime: atxPLCPDelay + arxTxSwitchTime + atxRampOnTime + atxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for PS, or 1/2 slot time after the center of the the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR. Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized. The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.Indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-Epecific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and asIFSTIme. The relationship between aMACProcessifine and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12. The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value. The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value. The current PHY's PLCP header length (in microseconds) if the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value. The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDuration
aTXRampOnTime linteger The maximum time (in microseconds) that the PMD takes to turn the Transmitter on. aTXRampOffTime linteger The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off. aTXRFDelay linteger The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for FH, or 1/2 chip period prior to the center of the corresponding slot for infrared (IR). aRXRFDelay linteger The nominal time (in microseconds) between the end of a symbol at the air linterface to the Issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for DS, or 1/2 slot time after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR. aAirPropagationTime linteger linteger The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTANT.request primitive pursuant to a PHY-RXEND. Indication primitive (for response after SIPS) or PHY-CCA. Indication(IDLE) primitive (for response after SIPS) or PHY-CCA. Indication(IDLE) primitive (for response after SIPS) or PHY-CCA. Indication(IDLE) primitive (for response after SIPS) or PHY-CCA. Indication (IDLE) primitive (for response after SIPS) or PHY-CCA. Indication (IDLE) primitive (for response after SIPS) or PHY-CCA. Indication (IDLE) primitive (for response after SIPS) or PHY-CCA. Indication (IDLE) primitive (for response after SIPS) or PHY-CCA. Indication (IDLE) primitive (for response after SIPS) or PHY-CCA. Indication (IDLE) primitive (for response after SIPS) or PHY-CCA. Indication (IDLE) pri
Transmitter on. aTXRampOffTime integer The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off. The nominal time (in microseconds) between the Issuance of a PMD. DATA. request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH. Or 1/2 chip period prior to the center of the symbol for IPI, or 1/2 chip period prior to the center of the symbol for IPI, or 1/2 chip period prior to the center of the corresponding slot for infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air interface. The symbol for IPI, or 1/2 chip period after the center of the center of the corresponding slot for Infrared (IR). The nominal time (in microseconds) between the end of a symbol at the air interface to the Issuance of a PMD. DATA. Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for DS, or 1/2 slot time after the center of the symbol for IPI, or 1/2 chip period after the center of the symbol for IPI, or 1/2 chip period after the center of the symbol for IPI, or 1/2 chip period after the center of the symbol for IPI, or 1/2 chip period after the center of the symbol for IPI, or 1/2 chip period after the center of the symbol for IPI, or 1/2 chip period after the center of the symbol for IPI, or 1/2 chip period after the center of the symbol for IPI, or 1/2 chip period after the center of the symbol for IPI, or 1/2 chip period after the center of the symbol for IPI, or 1/2 chip period prior to the symbol for IPI, or 1/2 chip period after the center of the symbol for IPI, or 1/2 chip period prior the symbol for IPI, or 1/2 chip period prior to the symbol for IPI, or 1/2 chip period prior the symbol for IPI, or 1/2 chip period prior the symbol for IPI, or 1/2 chip period prior the symbol for IPI, or 1/2 chip period prior the symbol for IPI, or 1/2 chip period prior the symbol for IPI
Power Amplifier off.
PMD_DATA_request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for DS, or 1/2 slot time prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR). aRXRFDelay Integer The nominal time (in microseconds) between the end of a symbol at the air Interface to the Issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for DS, or 1/2 slot time after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR. aAirPropagationTime Integer Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized. The aximum time (in microseconds) available for the MAC to Issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific parameter because of its use, along with other PHY-specific parameter because of its use, along with other PHY-specific parameter because of its
interface to the Issuance of a PMD_DATA.Indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR. Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized. The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response after SIFS) or an an assistant on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aslotTime and asSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12. The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value. The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value. The current PHY's PLCP header length (in microseconds) in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncatel (((PPDUblis/PSDUbits)-1) × 10°)]. The total time to transmit a PPDU over the air is generated by the following
distance between the most distant allowable STAs that are slot synchronized. The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.Indication primitive (for response after SIFs) or PHY-CCA.Indication(IDLE) primitive (for response at any slot boundary following SIFs). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific parameter because of its use, along with other PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC. aslorTime and a SIFSTIme. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12. The current PHY's pramble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value. The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value. The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as calling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncatel (((PPDUblts/PSDUbits)-1) × 10 ³)]. The total time to transmit a PPDU over the air is generated by the following
TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication (IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlotTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12. aPreambleLength integer The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value. The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value. The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncatel ((PPDUblis/PSDUbits-) 1) × 10*)]. The total time to transmit a PPDU over the air is generated by the following
length of the modulated preamble is not an integral number of microseconds, the value Is rounded up to the next higher value. The current PHY'S PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value. The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncatel ((PPDUblits/PSDUblits)–1) × 10*)1. The total time to transmit a PPDU over the air is generated by the following
the length of the modulated header is not an integral number of microseconds, the value Is rounded up to the next higher value. aMPDUDurationFactor Integer The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncale(((PPDUbits/PSDUbits)-1) × 10 ⁹)]. The total time to transmit a PPDU over the air is generated by the following
WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUblits)-1) × 10 ³)]. The total time to transmit a PPDU over the air is generated by the following
equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10 ⁹) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10 ⁹) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the destreact octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength Integer The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin Integer The minimum size of the CW, in units of aSlotTime. aCWmax integer The maximum size of the CW, in units of aSlotTime.

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPS K or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subscarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. e) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.5 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.5 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related par	ameters		
	Table 17-4 is the list of timing parameters associated with the OFDM PLCP.			
	Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μ s ($T_{SHORT} + T_{LONG}$)
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 μ s ($T_{GI} + T_{FFT}$)	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 $\mu s (T_{GI} + T_{FFT})$
	$T_{G\vec{I}}$: GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μ s (10 × T_{FFT} /4)
	T_{LONG} : Long training sequence duration	8 μ s ($T_{GI2} + 2 \times T_{FFT}$)	16 µs $(T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$

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	17.3.2.4 Mathematical conventions in the signal descriptions	
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:	
	$r_{(RF)^{(i)}} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1)	
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency	
	The transmitted baseband signal is composed of contributions from several OFDM symbols.	
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$	
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.	
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.	
	$N_{ST}/2$	
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp\left(j2\pi k \Delta_f\right) (t - T_{GUARD}) $ (17-3)	
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GID}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.	

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	$8 + 8 = 16 \ \mu s$ $10 \times 0.8 = 8 \ \mu s$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \ \mu s$ $t_1 \ t_2 \ t_3 \ t_4 \ t_5 \ t_6 \ t_7 \ t_8 \ t_9 \ t_{10} \ GI2 \ T_1 \ T_2$ $GI \ SIGNAL \ GI \ Data 1$ $GI \ Data 2$ $Signal Detect, Coarse Freq. Channel and Fine Frequency RATE SERVICE + DATA DATA$
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{ST}/2} L_k \exp(j2\pi k \Delta_F (t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.3.5.7 Subcarrier m	nodulation mapping		
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d_0 , are formed by multiplying the resulting (I+jQ) value by a normalization factor d_0 , as described in Equation (17-20).		wided into groups of N_{BPSC} SK, 16-QAM, or 64-QAM and constellation mappings, and The output values, d, are	
	$d = (I + jQ) \times K_{MOD}$			(17-20)
	that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
	Table 17-6—Modulation-dependent normalization factor K _{MOD}		or K _{MOD}	
		Modulation	K_{MOD}	
		BPSK	1	
		QPSK	1/√2	
		I		
		16-QAM	1/√10	

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.
	See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

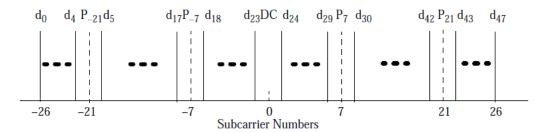


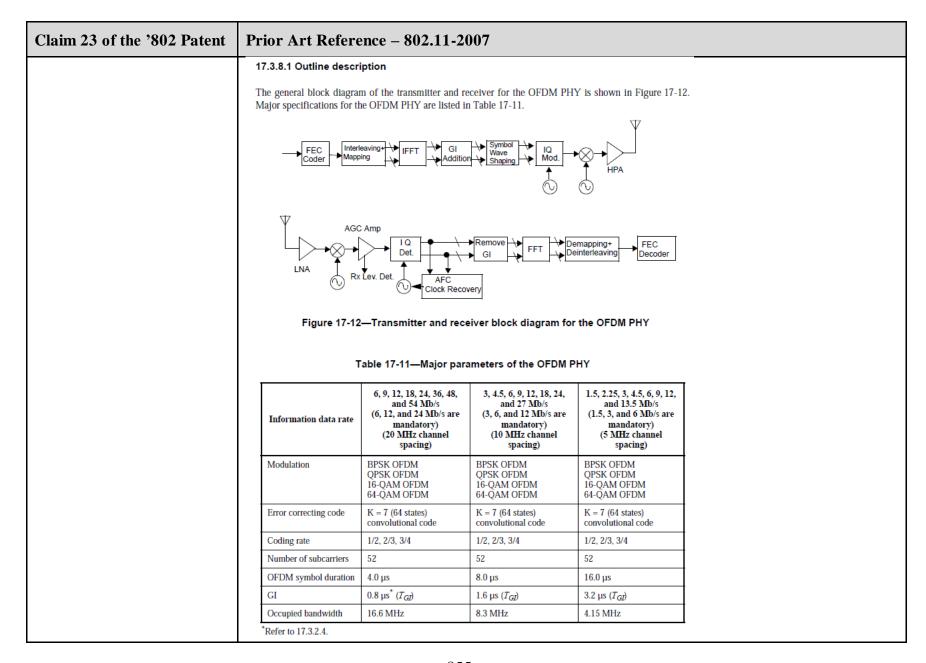
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

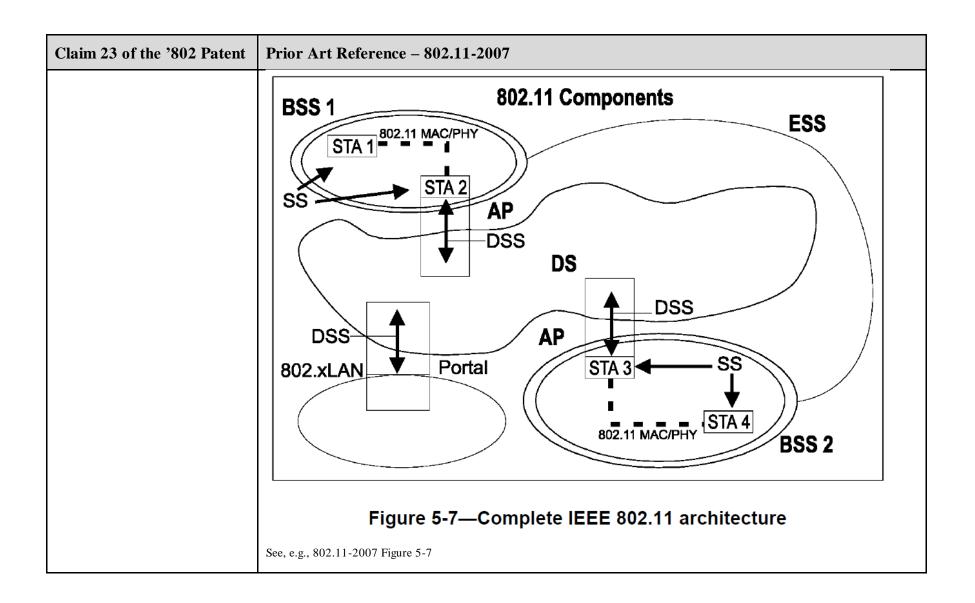
Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

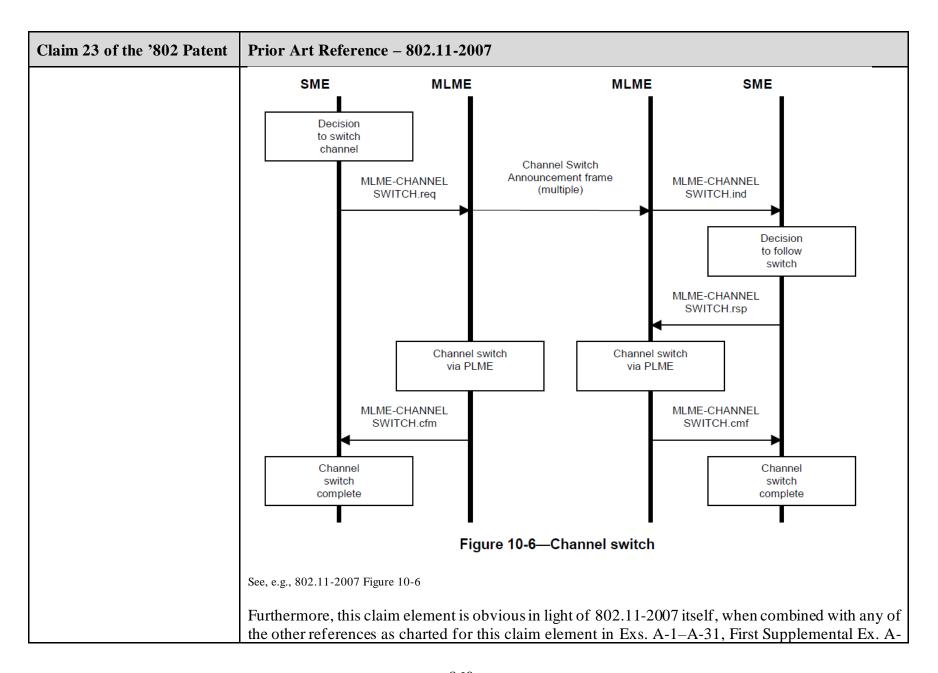


Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007						
	I.2.2 Transmit power levels						
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.						
	Table I.4—Transmit power level by regulatory domain						
	Frequency band (GHz)	United (Maximum out up to 6 dBi a (m	put power with ntenna gain)	Europe (EIRP)			
	5.15–5.25	40 (2.5 m	W/MHz)	200 mW	1		
	5.25-5.35	200 (12.5 1	nW/MHz)	200 mW			
	5.470-5.725	_	_	1 W			
	5.725–5.825	800 (50 m	iW/MHz)	_			
	5.15–5.25 5.25–5.35 5.470–5.725 5.725–5.825	(Maximum out up to 6 dBi a (m) 40 (2.5 m 200 (12.5 m – 800 (50 m	put power with intenna gain) W) W/MHz) mW/MHz)	(EIRP) 200 mW 200 mW 1 W —			
	Table I.5—U.S. public safety transmit power levels by regulatory domain U.S. public safety (mW)						
	•						
	Frequency band						
	Frequency band (GHz)	20 MHz channels	10 MHz channels	5 MHz channels			
		20 MHz	10 MHz	5 MHz			

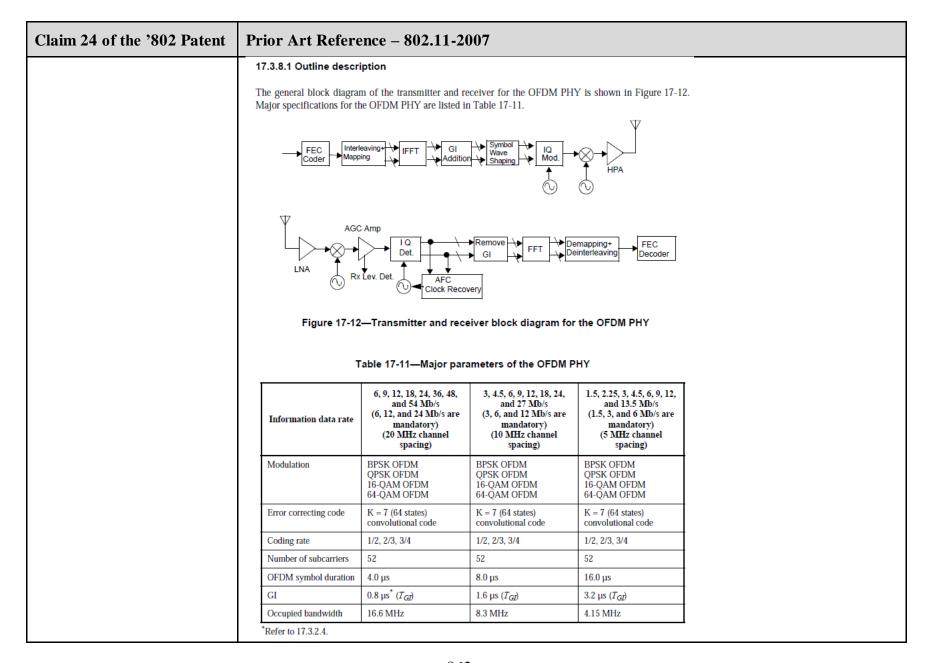
Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





Claim 23 of the '802 Patent	Prior Art Reference – 802.11-2007
	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
[24.1] An electronic circuit comprising:	To the extent the preamble is limiting, 802.11-2007 discloses "An electronic circuit comprising."



Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	Furthermore, this claim element is obvious in light of 802.11-2007 itself, when combined with any of the other references as charted for this claim element in Exs. A-1–A-31, First Supplemental Ex. A-Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart.
[24.2] a first down-converter circuit having a first input coupled to receive a first upconverted signal, a second input coupled to receive a first	802.11-2007 discloses "a first down-converter circuit having a first input coupled to receive a first up-converted signal, a second input coupled to receive a first demodulation signal having a first RF frequency, and an output, wherein the first down-converter circuit outputs a first down-converted signal on the first down-converter output." See, e.g.:
demodulation signal having a first RF frequency, and an output, wherein the first	1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.
down-converter circuit	See, e.g., 802.11-2007 § 1.1
outputs a first down-converted signal on the first down-converter output;	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
	5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.
	5.1.1.2 Media impact on design and performance The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs
	a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration
	e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,

aSIFSTime,

aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

aTxPLCPDelay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin, aCWmax

acv

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description	
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.	
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.	
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.	
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.	
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrmraroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.	
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).	
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.	

Name	Type	Description
aRxTxSwitchTime	Integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	Integer	The nominal time (in microseconds) between the Issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIFS) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength, + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + ((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NOBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. b) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers number

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP. Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N _{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	$T_{PREAMBLE}$: PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 $\mu s (T_{SHORT} + T_{LONG})$	64 μ s ($T_{SHORT} + T_{LONG}$)
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 μ s ($T_{GI} + T_{FFT}$)	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 $\mu s (T_{GI} + T_{FFT})$
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (T _{FFT} /2)
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 μs (10 × T _{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 $\mu s (10 \times T_{FFT}/4)$
	T _{LONG} : Long training sequence duration	8 $\mu s (T_{GI2} + 2 \times T_{FFT})$	16 μ s ($T_{GI2} + 2 \times T_{FFT}$)	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$
	See, e.g., 802.11-2007 § 17.3.2.3		•	·

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	17.3.2.4 Mathematical conventions in the signal descriptions			
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:			
	$r_{(RF)^{(j)}} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\} $ (17-1)			
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency			
	The transmitted baseband signal is composed of contributions from several OFDM symbols.			
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$			
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.			
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.			
	$N_{\rm ST}/2$			
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)			
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GID}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.			

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ (17-4)
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k = -N_{cov}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

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	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$\mathbf{d} = (\mathbf{I} + \mathbf{j}\mathbf{Q}) \times \mathbf{K}_{\text{MOD}}$			(17-20)
	from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6. Table 17-6—Modulation-dependent normalization factor K _{MOD}			
			ent normalization factor	- K _{MOD}
		Modulation	K _{MOD}	· K _{MOD}
		Modulation BPSK		· K _{MOD}
			${ m K_{MOD}}$	· K _{MOD}
		BPSK	K _{MOD}	· K _{MOD}

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	17.3.5.8 Pilot subcarriers
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9. See, e.g., 802.11-2007 § 17.3.5.8

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}$$
, $k = 0, ... N_{SD} - 1, n = 0, ... N_{SYM} - 1$ (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

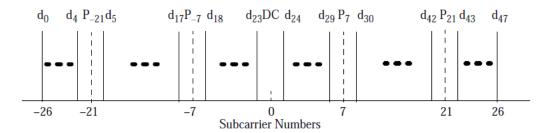


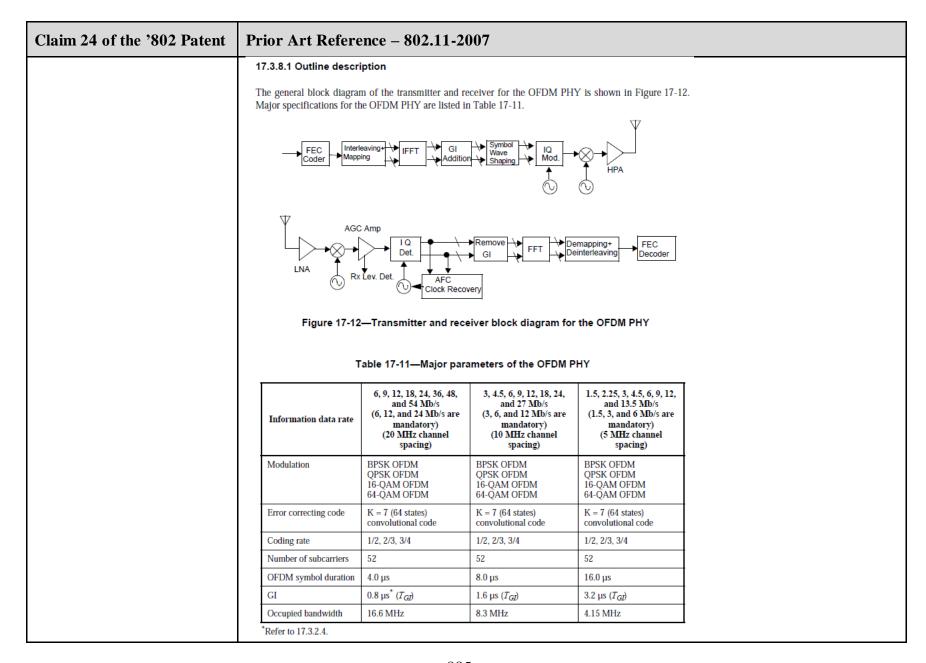
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
 (17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

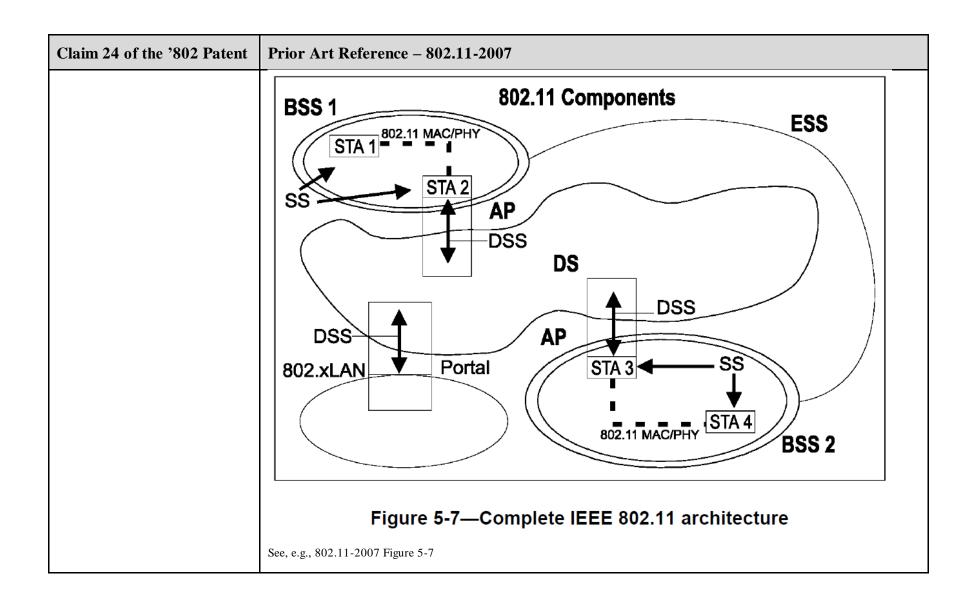
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	See, e.g., 802.11-2007 § 17.3.5.9

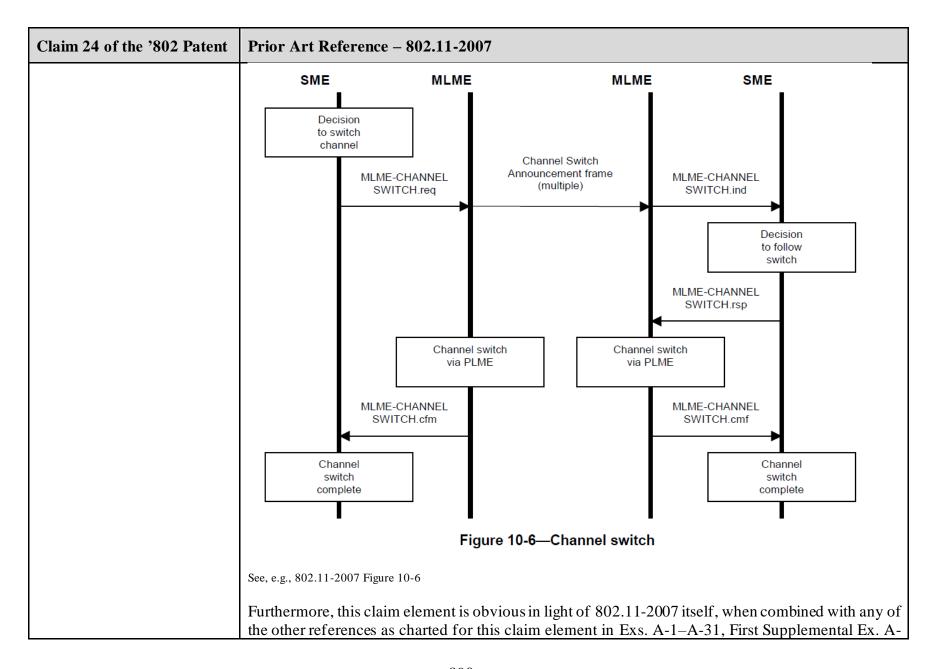


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

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	I.2.2 Transmit power levels				
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.				
	Table I.4—Transmit power level by regulatory domain				
	Frequency band (GHz)	(Maximum out up to 6 dBi a	put power with ntenna gain)	Europe (EIRP)	
	5.15–5.25	40 (2.5 mW/MHz)		200 mW	7
	5.25–5.35	200 (12.5 mW/MHz)		200 mW	1
	5.470-5.725	_		1 W	1
	5.725-5.825	800 (50 mW/MHz)		_	
	(GHz) up to 6 dBi antenna gain) (mW) 5.15–5.25 40 (2.5 mW/MHz) 5.25–5.35 200 (12.5 mW/MHz) 5.470–5.725 —				
	Table I.5—U.S. public sa		ower levels by S. public safety (m		in
	Frequency band				
	Frequency band (GHz)	20 MHz channels	10 MHz channels	5 MHz channels	
		20 MHz	10 MHz	5 MHz	

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	I.2.3 Transmit spectrum mask
	For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, –20 dBr at 5.5 MHz frequency offset, –28 dBr at 10 MHz frequency offset, and –40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale) -20 dBt
	Typical Signal Spectrum (an example)
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask
	See, e.g., 802.11-2007 § I.2.3





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[24.3] a second down-	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "a second down-converter circuit having a first input coupled to receive the
converter circuit having a first input coupled to receive the first up-converted signal, a second input coupled to receive a second	first up-converted signal, a second input coupled to receive a second demodulation signal having a second RF frequency different than the first RF frequency, and an output, wherein the second down-converter outputs a second down-converted signal on the second down-converter output, wherein the first up-converted signal comprises a first signal modulated at the first RF frequency and a second signal modulated at the second RF frequency." See, e.g.:
demodulation signal having a second RF frequency different than the first RF frequency, and an output, wherein the second down-converter	1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1
outputs a second down- converted signal on the second down-converter output, wherein the first up- converted signal comprises a	5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations.
first signal modulated at the first RF frequency and a second signal modulated at the second RF frequency; and	 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE Std 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance
	The PHYs used in IEEE Std 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every

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	other STA is invalid (i.e., STAs may be "hidden" from each other) f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks

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	this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC

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	Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1
	7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57.
	See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame.
	See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime,
aSIFSTime,
aCCATime,
aPHY-RX-START-Delay,
aRxTxTurnaroundTime,
aTxPLCPDelay,
aRxPLCPDelay,
aRxTxSwitchTime,
aTxRampOnTime,
aTxRampOffTime,
aTxRFDelay,
aRxFFDelay,
aAirPropagationTime,
aMACProcessingDelay,

aPreambleLength, aPLCPHeaderLength,

aMPDUDurationFactor, aMPDUMaxLength,

aCWmin, aCWmax)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrunaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

37		D 11
Name aRxTxSwitchTime	Type	Description The nominal time (in microseconds) that the PMD takes to switch from Receive
aTxRampOnTime	Integer	to Transmit. The maximum time (in microseconds) that the PMD takes to turn the
		Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-TXSTND.indication primitive (for response after SIFS) or PHY-CCA.Indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value Is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and

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	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NOBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. b) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. b) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers num
	500, 0.g., 002.11 2007 § 17.5.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP.					
	Table 17-4—Timing-related parameters					
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)		
	N_{SD} : Number of data subcarriers	48	48	48		
	N_{SP} : Number of pilot subcarriers	4	4	4		
	N_{ST} : Number of subcarriers, total	52 $(N_{SD} + N_{SP})$	52 (N _{SD} + N _{SP})	$52 (N_{SD} + N_{SP})$		
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)		
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 µs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$		
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs ($T_{SHORT} + T_{LONG}$)		
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 μ s ($T_{GI} + T_{FFT}$)	8.0 μ s ($T_{GI} + T_{FFT}$)	16.0 $\mu s (T_{GI} + T_{FFT})$		
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)		
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)		
	T _{SYM} : Symbol interval	$4 \mu s (T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (T _{GI} + T _{FFT})		

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)	
	T_{SHORT} : Short training sequence duration	8 μ s (10 \times T_{FFT} /4)	16 μs (10 × T _{FFT} /4)	32 μ s (10 × T_{FFT} /4)	
	T_{LONG} : Long training sequence duration	8 µs $(T_{GI2} + 2 \times T_{FFT})$	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$	

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)^{(i)}} = Re\{r\langle t\rangle \exp\langle j2\pi f_c t\rangle\}$ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $ (17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT}=1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GIZ}), and for data OFDM symbols (= T_{GI}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ (17-4)
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} (b)
	Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations		
	The following descriptions of the discrete time implementation are informational.		
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes		

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	8 + 8 = 16 μs 10 × 0.8 = 8 μs 2 × 0.8 + 2 × 3.2 = 8.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs 0.8 + 3.2 = 4.0 μs GI SIGNAL GI Data 1 GI Data 2
	Signal Detect, AGC, Diversity Selection Coarse Freq. Channel and Fine Frequency RATE Offset Estimation Offset Estimation Timing Synchronize SERVICE + DATA DATA LENGTH
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

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A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{eff}/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \, \mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007			
	17.3.5.7 Subcarrier modulation mapping			
	The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 17-10, with the input bit, b_0 , being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD} , as described in Equation (17-20).			
	$\mathbf{d} = (\mathbf{I} + \mathbf{j}\mathbf{Q}) \times \mathbf{K}_{\text{MOD}}$			(17-20)
	from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6. Table 17-6—Modulation-dependent normalization factor K _{MOD}			
			ent normalization factor	· K _{MOD}
		Modulation	K _{MOD}	· K _{MOD}
		Modulation BPSK		· K _{MOD}
			${ m K_{MOD}}$	· K _{MOD}
		BPSK	K _{MOD}	· K _{MOD}

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007		
	17.3.5.8 Pilot subcarriers		
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.		
	See, e.g., 802.11-2007 § 17.3.5.8		

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA} n(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

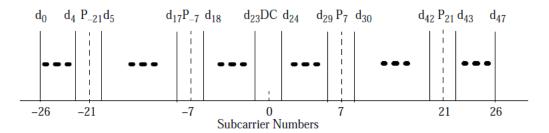


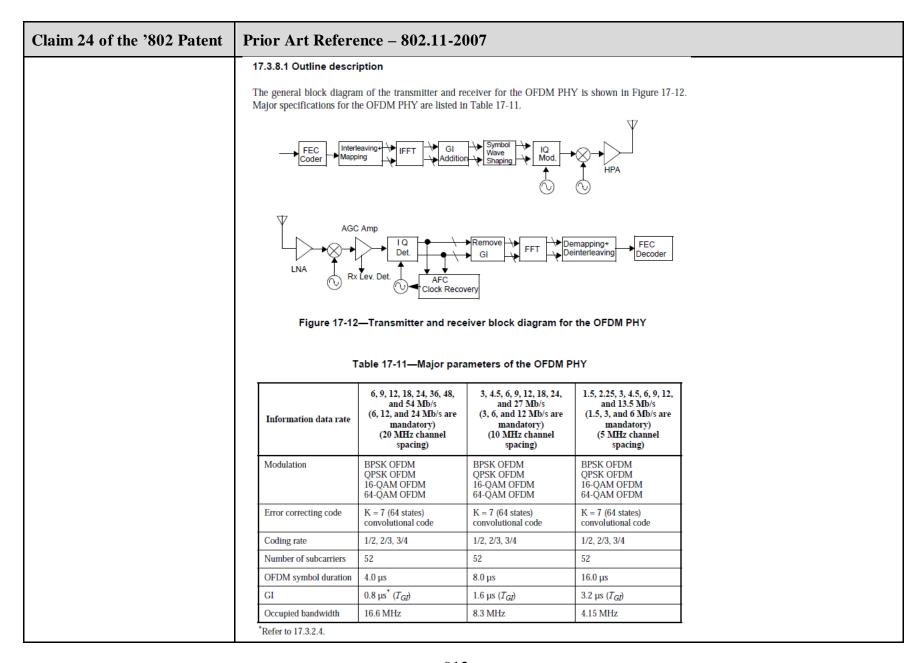
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

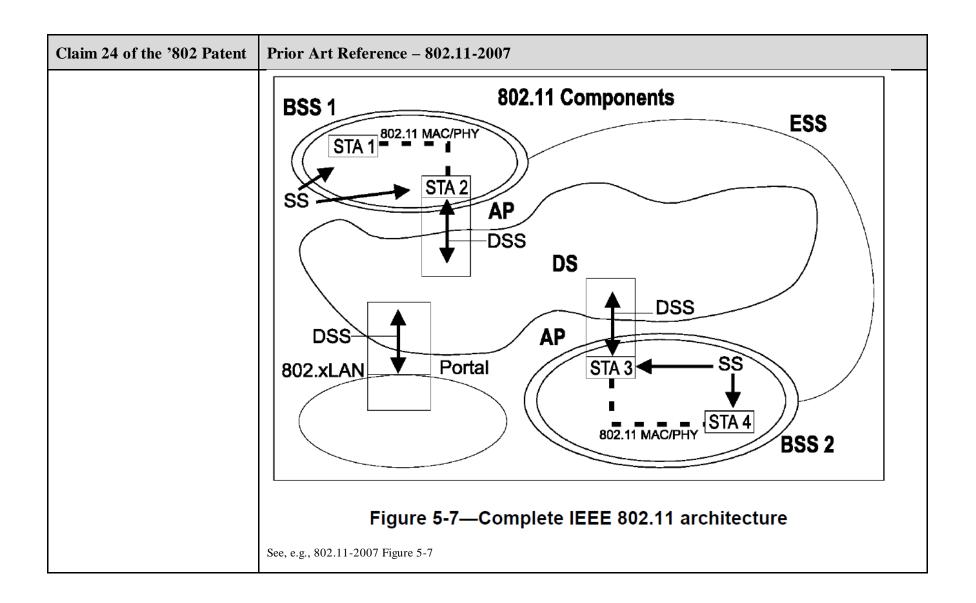
Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.5.9

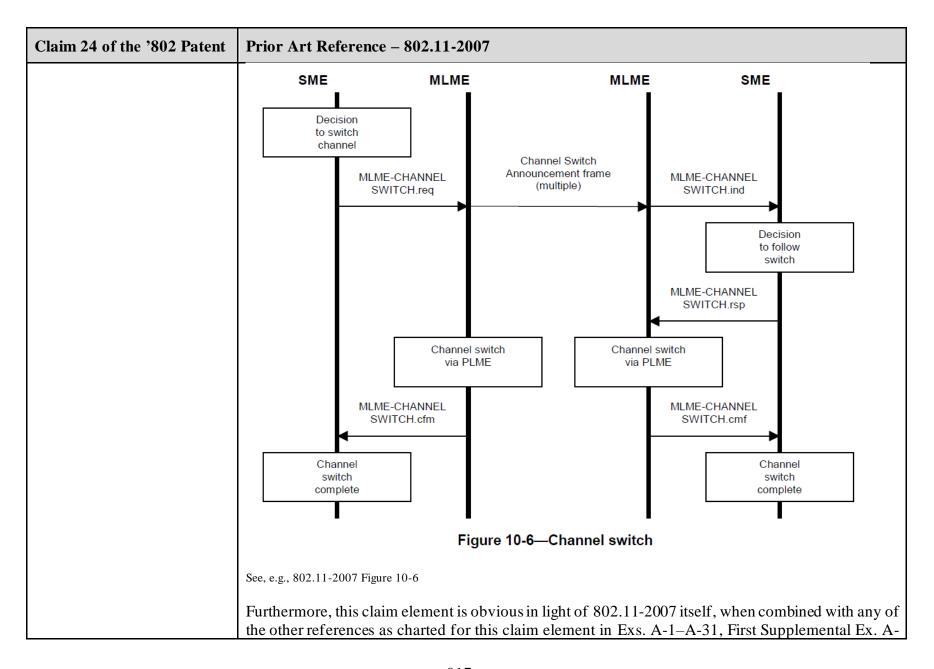


Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

_	Prior Art Reference – 802.11-2007				
I.2.2 Transmit power levels					
The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.					
Table I.4—Transmit power level by regulatory domain					
	Frequency band (GHz)			Europe (EIRP)	
	5.15-5.25	40 (2.5 mW/MHz)		200 mW	7
	5.25-5.35	200 (12.5 mW/MHz)		200 mW	
	5.470-5.725			1 W	
	5.725-5.825	800 (50 mW/MHz)		_	
Tab	Table I.5—U.S. public safety transmit power levels by regulatory domain U.S. public safety (mW)			ain	
	(GHz)	20 MHz channels	10 MHz channels	5 MHz channels	
	4.94–4.99 low power	100	50	25	
	4.94–4.99 high power 2000 1000		500		
See e.g. 802.11.2007.8.12.2					
	maximum allov Table I.5.	Table I.4—Tran Frequency band (GHz) 5.15–5.25 5.25–5.35 5.470–5.725 5.725–5.825 Table I.5—U.S. public sate (GHz) 4.94–4.99 low power	Table I.5. Table I.4. Transmit power level United (Maximum out up to 6 dBi a (m)	Table I.5.	Table 1.4—Transmit power level by regulatory domain

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative
	to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example) -40 dBr
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask See, e.g., 802.11-2007 § I.2.3





Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
[24.4] a filter having an input coupled to the output of the first down-converter and the output of the second down-converter, and in accordance therewith, the filter receives the first and second down-converted signals.	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art. Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or from the known problems and predictable solutions as embodied in these references. Further motivations to combine references and additional details may be found in the Cover Pleading and First Supplemental Ex. A-Obviousness Chart. 802.11-2007 discloses "a filter having an input coupled to the output of the first down-converter and the output of the second down-converter, and in accordance therewith, the filter receives the first and second down-converted signals." See, e.g.: 1.1 Scope The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area. See, e.g., 802.11-2007 § 1.1 5.1.1 How WLAN systems are different Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard. This standard does not provide information to meet these country-specific radio regulations. 5.1.1.1 Destination address does not equal destination location In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs, In IEEE 8td 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location. 5.1.1.2 Media impact on design and performance The PHYs used in IEEE 8td 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs a) Use a medium that has neither absolute nor readily observable boundaries outside of which STAs with conformant PHY transceivers are known to be unable to receive network frames
	with conformant PHY transceivers are known to be unable to receive network frames b) Are unprotected from other signals that may be sharing the medium c) Communicate over a medium significantly less reliable than wired PHYs d) Have dynamic topologies e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be "hidden" from each other)
	f) Have time-varying and asymmetric propagation properties g) May experience interference from logically disjoint IEEE 802.11 networks operating in overlapping areas

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	Because of limitations on wireless PHY ranges, WLANs intended to cover reasonable geographic distances may be built from basic coverage building blocks. When providing QoS services it should be understood that the MAC endeavors to provide QoS "service guarantees" within the limitations of the medium properties identified above. In other words, particularly in unlicensed spectrum, true guarantees are often not possible. However, gradations of service are always possible; and in sufficiently controlled environments, QoS guarantees can truly be made.
	5.1.1.3 The impact of handling mobile STAs One of the requirements of IEEE Std 802.11 is to handle <i>mobile</i> as well as <i>portable</i> STAs. A <i>portable</i> STA is one that is moved from location to location, but that is only used while at a fixed location. <i>Mobile</i> STAs actually access the LAN while in motion.
	For technical reasons, it is not sufficient to handle only portable STAs. Propagation effects blur the distinction between portable and mobile STAs; stationary STAs often appear to be mobile due to propagation effects.
	Another aspect of mobile STAs is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a STA's receiver will always be powered on.
	See, e.g., 802.11-2007 § 5.1.1 - § 5.1.1.3
	5.2 Components of the IEEE 802.11 architecture The IEEE 802.11 architecture consists of several components that interact to provide a WLAN that supports STA mobility transparently to upper layers. The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 5-1 shows two BSSs, each of which has two STAs that are members of the BSS. It is useful to think of the ovals used to depict a BSS as the coverage area within which the member STAs of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) This area is called the Basic Service Area (BSA). If a STA moves out of its BSA, it can no longer directly communicate with other STAs present in the BSA.
	See, e.g., 802.11-2007 § 5.2
	5.2.3 Distribution system (DS) concepts
	PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.
	Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	IEEE Std 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.
	Recognizing that the multiple media are <i>logically</i> different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.
	The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.
	An access point (AP) is any entity that has STA functionality and enables access to the DS, via the WM for associated STAs.
	See, e.g., 802.11-2007 § 5.2.3
	5.3.2 DSS The service provided by the DS is known as the DSS. This service is represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the service is used to cross media and possibly address space logical boundaries. An AP is a logical entity, and the functions described may be shared by one or more physical entities.
	The services that comprise the DSS are as follows: a) Association b) Disassociation c) Distribution d) Integration e) Reassociation f) QoS traffic scheduling (QoS facility only) DSSs are specified for use by MAC sublayer entities.
	Figure 5-7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.
	See, e.g., 802.11-2007 § 5.3.2
	5.4.4.1 TPC Radio regulations may require radio local area networks (RLANs) operating in the 5 GHz band to use transmitter power control, involving specification of a regulatory maximum transmit power and a mitigation requirement for each allowed channel, to reduce interference with satellite services. The TPC service is used to satisfy this regulatory requirement.

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	The TPC service provides for the following: — Association of STAs with an AP in a BSS based on the STAs' power capability. — Specification of regulatory and local maximum transmit power levels for the current channel. — Selection of a transmit power for each transmission in a channel within constraints imposed by regulatory requirements. — Adaptation of transmit power based on a range of information, including path loss and link margin estimates.
	See, e.g., 802.11-2007 § 5.4.4.1 7.3.2.20 Channel Switch Announcement element The Channel Switch Announcement element is used by an AP in a BSS or a STA in an IBSS to advertise when it is changing to a new channel and the channel number of the new channel. The format of the Channel Switch Announcement element is shown in Figure 7-57. See, e.g., 802.11-2007 § 7.3.2.20
	10.3.11 Spectrum management protocol layer model The layer management extensions for measurement and channel switching assume a certain partition of spectrum management functionality between the MLME and SME. This partitioning assumes that policy decisions (e.g., regarding measurement and channel switching) reside in the SME, while the protocol for measurement, switch timing, and the associated frame exchanges resides within the MLME (see Figure 10-2).
	The informative diagrams within this subclause further illustrate the spectrum management protocol model adopted. Figure 10-3 and Figure 10-4 depict the measurement process for a peer STA to accept and reject a measurement request, respectively. Figure 10-5 illustrates the TPC adaptation process. Lastly, Figure 10-6 depicts the management process for a channel switch using a Channel Switch Announcement frame. See, e.g., 802.11-2007 § 10.3.11

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters: PLME-CHARACTERISTICS.confirm

aSlotTime, aSIFSTime, aCCATime,

aPHY-RX-START-Delay,

aRxTxTurnaroundTime,

a Tx PLC PD elay,

aRxPLCPDelay,

aRxTxSwitchTime,

aTxRampOnTime,

aTxRampOffTime,

aTxRFDelay,

aRxRFDelay,

aAirPropagationTime,

aMACProcessingDelay,

aPreambleLength,

aPLCPHeaderLength,

aMPDUDurationFactor,

aMPDUMaxLength,

aCWmin,

aCWmax

)

The values assigned to the parameters is as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aPHY-RX-START-Delay	integer	The delay, in microseconds, from a point in time specified by the PHY to the issuance of the PHY-RXSTART.indication primitive.
aRxTxTurnaroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RXTXTrmraroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver the last bit of a received frame from the PMD receive path to the MAC.

37	T	P 14
Name aRxTxSwitchTime	Type	Description The nominal time (in microseconds) that the PMD takes to switch from Receive
		to Transmit. The maximum time (in microseconds) that the PMD takes to turn the
aTxRampOnTime	integer	Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH. or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagationTime	integer	Twice the propagation time (in microseconds) for a signal to cross the maximum distance between the most distant allowable STAs that are slot synchronized.
aMACProcessingDelay	integer	The maximum time (in microseconds) available for the MAC to issue a PHY-TXSTART.request primitive pursuant to a PHY-RXEND.indication primitive (for response after SIES) or PHY-CCA.indication(IDLE) primitive (for response at any slot boundary following SIFS). This constraint on MAC performance is defined as a PHY-specific parameter because of its use, along with other PHY-specific time delays, in calculating the two PHY characteristics of primary concern to the MAC: aSlofTime and aSIFSTime. The relationship between aMACProcessingTime and the IFS and slot timing is described in 9.2.10 and illustrated in Figure 9-12.
aPreambleLength	integer	The current PHY's preamble length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value is rounded up to the next higher value.
aPLCPHeaderLength	integer	The current PHY's PLCP header length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value is rounded up to the next higher value.
aMPDUDurationFactor	Integer	The overhead added by the PHY to the MPDU as it is transmitted through the WM expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)-1) × 10³]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer µs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10³) + (8 × PSDUoctets) / data rate where data rate is in Mb/s. The total time (in µs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10³) + (8 × N)) / data rate] + 1, where data rate is in Mb/s and where N counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP header.
aMPDUMaxLength	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	17.1 Introduction
	This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The OFDM system provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mb/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mb/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.
	The OFDM system also provides a "half-clocked" operation using 10 MHz channel spacings with data communications capabilities of 3, 4.5, 6, 9, 12, 18, 24, and 27 Mb/s. The support of transmitting and receiving at data rates of 3, 6, and 12 Mb/s is mandatory when using 10 MHz channel spacing. The halfclocked operation doubles symbol times and clear channel assessment (CCA) times when using 10 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in 4.9 GHz and 5 GHz bands is in Annex I and Annex J.
	The OFDM system also provides a "quarter-clocked" operation using 5 MHz channel spacing with data communication capabilities of 1.5, 2.25, 3, 4.5, 6, 9, 12, and 13.5 Mb/s. The support of transmitting and receiving at data rates of 1.5, 3, and 6 Mb/s is mandatory when using 5 MHz channel spacing. The quarterclocked operation quadruples symbol times and CCA times when using 5 MHz channel spacing. The regulatory requirements and information regarding use of this OFDM system in the 4.9 GHz band is in Annex I and Annex J.
	See, e.g., 802.11-2007 § 17.1
	17.3.2.1 Overview of the PPDU encoding process The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:
	a) Produce the PLCP Preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details. b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped on to a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for

Claim 24 of the '802 Patent	Prior Art Reference – 802.11-2007
	prepending a GI as described subsequently for data transmission with BPSK-OFDM modulated at coding rate 1/2. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details. c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (NDBPS), the coding rate (R), the number of bits in each OFDM subcarrier (NBPSC), and the number of coded bits per OFDM symbol (NCBPS). Refer to 17.3.2.2 for details. d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of NDBPS. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details. e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details. f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details. g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details. h) Divide the encoded bit string into groups of NCBPS bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.7 for details. j) Divide the resulting coded and interleaved data string into groups of NCBPS bits. For each of the bit groups, convert the bit group jinto a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details. j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered
	See, e.g., 802.11-2007 § 17.3.2.1

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	17.3.2.3 Timing related parameters Table 17-4 is the list of timing parameters associated with the OFDM PLCP.			
	Table 17-4—Timing-related parameters			
	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	N_{SD} : Number of data subcarriers	48	48	48
	N_{SP} : Number of pilot subcarriers	4	4	4
	N_{ST} : Number of subcarriers, total	$52 (N_{SD} + N_{SP})$	52 (N _{SD} + N _{SP})	52 (N _{SD} + N _{SP})
	Δ_{F} : Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)	0.15625 MHz (= 10 MHz/64)	0.078125 MHz (= 5 MHz/64)
	T_{FFT} : Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs $(1/\Delta_F)$	6.4 μs $(1/\Delta_F)$	12.8 μs $(1/\Delta_F)$
	T _{PREAMBLE} : PLCP preamble duration	16 μs $(T_{SHORT} + T_{LONG})$	32 μs $(T_{SHORT} + T_{LONG})$	64 μs $(T_{SHORT} + T_{LONG})$
	T_{SIGNAL} : Duration of the SIGNAL BPSK-OFDM symbol	4.0 $\mu s (T_{GI} + T_{FFT})$	8.0 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)	16.0 $\mu s (T_{GI} + T_{FFT})$
	T_{GI} : GI duration	0.8 μs (<i>T_{FFT}</i> /4)	1.6 μs (<i>T_{FFT}</i> /4)	3.2 μs (<i>T_{FFT}</i> /4)
	T_{GI2} : Training symbol GI duration	1.6 μs (<i>T_{FFT}</i> /2)	3.2 μs (<i>T_{FFT}</i> /2)	6.4 μs (<i>T_{FFT}</i> /2)
	T_{SYM} : Symbol interval	4 μs $(T_{GI} + T_{FFT})$	8 μ s ($T_{GI} + T_{FFT}$)	16 μs (<i>T_{GI}</i> + <i>T_{FFT}</i>)

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	Parameter	Value (20 MHz channel spacing)	Value (10 MHz channel spacing)	Value (5 MHz channel spacing)
	T_{SHORT} : Short training sequence duration	8 µs $(10 \times T_{FFT}/4)$	16 μs (10 × T _{FFT} /4)	32 μs (10 × T _{FFT} /4)
	T _{LONG} : Long training sequence duration	8 $\mu s (T_{GI2} + 2 \times T_{FFT})$	16 $\mu s (T_{GI2} + 2 \times T_{FFT})$	32 $\mu s (T_{GI2} + 2 \times T_{FFT})$
	See, e.g., 802.11-2007 § 17.3.2.3	•		· · · · · · · · · · · · · · · · · · ·

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	17.3.2.4 Mathematical conventions in the signal descriptions
	The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:
	$r_{(RF)(t)} = Re\{r\langle t\rangle \exp(j2\pi f_c t)\} $ (17-1)
	where $Re(.)$ represents the real part of a complex variable f_c denotes the carrier center frequency
	The transmitted baseband signal is composed of contributions from several OFDM symbols.
	$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) $ $(17-2)$
	The subframes of which Equation (17-2) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μ s for 20 MHz channel spacing, 32 μ s for 10 MHz channel spacing, and 64 μ s for 5 MHz channel spacing, and t_{DATA} is equal to 20 μ s for 20 MHz channel spacing, 40 μ s for 10 MHz channel spacing, and 80 μ s for 5 MHz channel spacing.
	All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k , with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.
	$N_{ST}/2$
	$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k = -N_{ST}/2} C_k \exp(j2\pi k \Delta_f)(t - T_{GUARD}) $ (17-3)
	The parameters Δ_F and N_{ST} are described in Table 17-4. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μ s), for the long training sequence (= T_{GID}), and for data OFDM symbols (= T_{GID}). (Refer to Table 17-4.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_{T}(t)$, of duration T , accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_{T}(t)$, depending on the value of the duration parameter, T , may extend over more than one period, T_{FFT} . In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 17-2 illustrates the possibility of extending the windowing function over more than one period, T_{FFT} , and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (17-4). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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	$w_{T}(t) = \begin{cases} \sin^{2}\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^{2}\left(\frac{\pi}{2}(0.5 - (t - T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} $ $(17-4)$
	In the case of vanishing T_{TR} , the windowing function degenerates into a rectangular pulse of duration T . The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR} , as shown in Figure 17-2. The transition time, T_{TR} , is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.
	$T = T_{GI} + T_{FFT}$ T_{GUARD} $= T_{GI}$ T_{FFT} T_{TR}
	$T = T_{GIZ} + 2T_{FFT}$ T_{GUARD} $= T_{GIZ}$ T_{FFT} T_{FFT} T_{TR} T_{TR} (b) Figure 17-2—Illustration of OFDM frame with cyclic extension and windowing for
	(a) single reception or (b) two receptions of the FFT period See, e.g., 802.11-2007 § 17.3.2.4 Eq. (17-1)

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	17.3.2.5 Discrete time implementation considerations
	The following descriptions of the discrete time implementation are informational.
	In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters $T=4.0~\mu s$ and a $T_{TR}=100~n s$ is applied, and the signal is sampled at 20 Msample/s, it becomes

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	$w_{T}[n] = w_{T}(nT_{S}) = \begin{cases} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{cases} $ (17-5)
	The common way to implement the inverse Fourier transform, as shown in Equation (17-3), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 17-3. After performing an IFFT, the output is cyclically extended to the desired length.
	Null
	Figure 17-3—Inputs and outputs of inverse Fourier transform
	See, e.g., 802.11-2007 § 17.3.2.5

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	17.3.3 PLCP preamble (SYNC)
	The PLCP Preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 17-4 and described in this subclause. The timings described in this subclause and shown in Figure 17-4 are for 20 MHz channel spacing. They are doubled for half-clocked (i.e., 10 MHz) channel spacing and are quadrupled for quarter-clocked (i.e., 5 MHz) channel spacing.
	$8 + 8 = 16 \mu\text{s}$ $10 \times 0.8 = 8 \mu\text{s}$ $2 \times 0.8 + 2 \times 3.2 = 8.0 \mu\text{s}$ $10 \times 0.8 + 3.2 = 4.0 \mu\text{s}$ $10 \times 0.8 + 3.2 = 4.$
	AGC, Diversity Offset Estimation Offset Estimation LENGTH Selection Timing Synchronize
	Figure 17-4—OFDM training structure
	Figure 17-4 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 μ s. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

$$0, 0, 0, -1 - j, 0, 0, 0, -1 - j, 0, 0, 0, 1 + j, 0, 0$$
 (17-6)

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k = -N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k \Delta_F t)$$
(17-7)

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8 \,\mu\text{s}$. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N--/2}^{N_{ST}/2} L_k \exp(j2\pi k \Delta_F(t - T_{G12}))$$
 (17-9)

where

$$T_{G,12} = 1.6 \,\mu s$$

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8 \,\mu s$.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT})$$
(17-10)

See, e.g., 802.11-2007 § 17.3.3

Prior Art Reference	- 802.11-2007		
17.3.5.7 Subcarrier m	nodulation mapping		
RATE requested. The en (1, 2, 4, or 6) bits and co constellation points. The illustrated in Figure 17-1	shall be modulated by using BF acoded and interleaved binary sonverted into complex number e conversion shall be perform 10, with the input bit, b ₀ , being the resulting (I+jQ) value	serial input data shall be divented in the serial input data shall be divented in the serial beautions and serial in the stream in the stream.	vided into groups of N_{BPSC} SK, 16-QAM, or 64-QAM ed constellation mappings, . The output values, d, are
$\mathbf{d} = (\mathbf{I} + \mathbf{j}\mathbf{Q}) \times \mathbf{K}_{\text{MOD}}$			(17-20)
that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 17-1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.			
Table	17-6—Modulation-depend	dent normalization fact	or K _{MOD}
	Modulation	$\mathbf{K}_{\mathbf{MOD}}$	
	BPSK	1	
	QPSK	1/√2	
	16-QAM	1/√10	
ĺ	64-QAM	1/√42	

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	17.3.5.8 Pilot subcarriers	
	In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers -21, -7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.	
	See, e.g., 802.11-2007 § 17.3.5.8	

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of N_{SD} = 48 complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k, n} \equiv d_{k+N_{SD} \times n}, \qquad k = 0, \dots N_{SD} - 1, n = 0, \dots N_{SYM} - 1$$
 (17-21)

The number of OFDM symbols, N_{SYM} , was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA, n}(t) = w_{TSYM}(t) \begin{pmatrix} N_{SD} - 1 \\ \sum_{k=0}^{N} d_{k, n} \exp((j2\pi M(k) \Delta_F (t - T_{GI}))) \\ N_{ST} / 2 \\ + P_{n+1} \sum_{k=-N_{ST} / 2} P_k \exp(j2\pi k \Delta_F (t - T_{GI})) \\ k = -N_{ST} / 2 \end{pmatrix}$$
(17-22)

where the function, M(k), defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0^{th} (dc) subcarrier.

$$M(k) = \begin{cases} k - 26 & 0 \le k \le 4 \\ k - 25 & 5 \le k \le 17 \\ k - 24 & 18 \le k \le 23 \\ k - 23 & 24 \le k \le 29 \\ k - 22 & 30 \le k \le 42 \\ k - 21 & 43 \le k \le 47 \end{cases}$$

$$(17-23)$$

The contribution of the pilot subcarriers for the n^{th} OFDM symbol is produced by inverse Fourier transform of sequence P, given by

The polarity of the pilot subcarriers is controlled by the sequence, p_n , which is a cyclic extension of the 127 elements sequence and is given by

The sequence p_n can be generated by the scrambler defined by Figure 17-7 when the all ones initial state is used, and by replacing all 1's with -1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0 , multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 17-11. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0^{th} subcarrier) is not used.

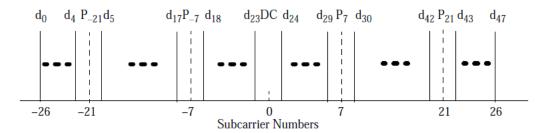


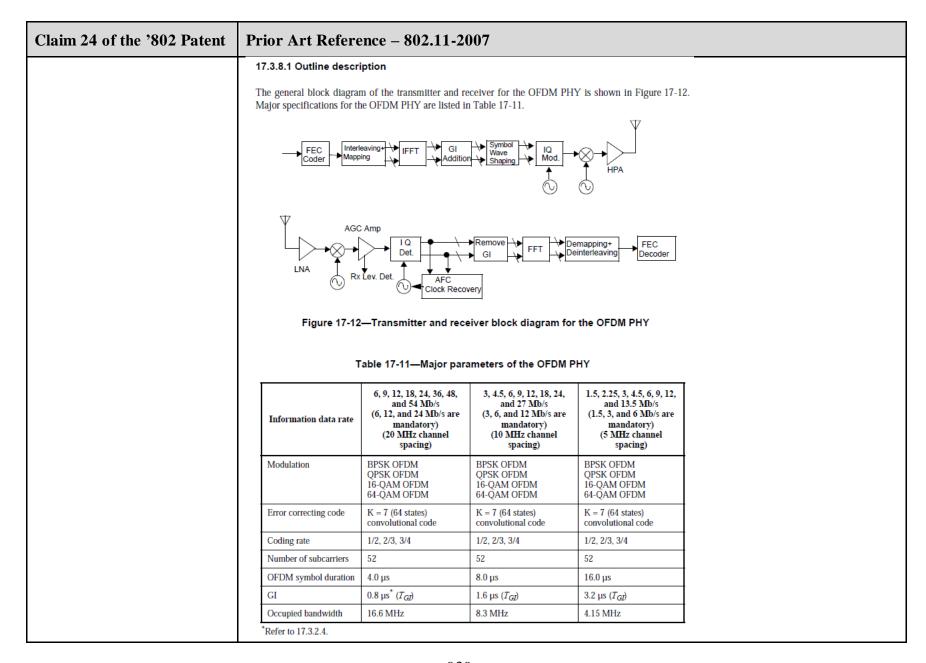
Figure 17-11—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA, n}(t - nT_{SYM})$$
(17-26)

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7). The final output of these operations is also shown in G.8.

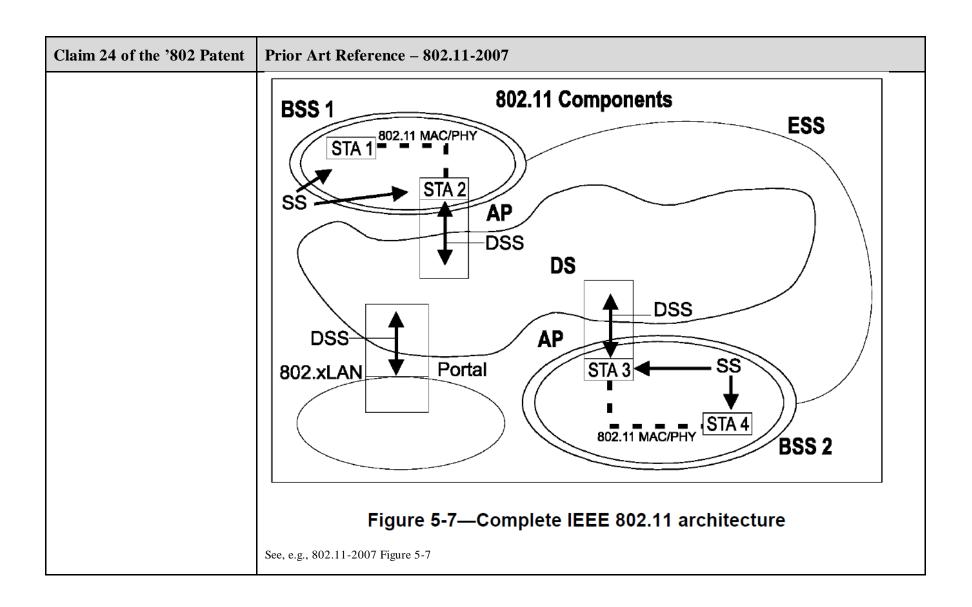
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	See, e.g., 802.11-2007 § 17.3.5.9

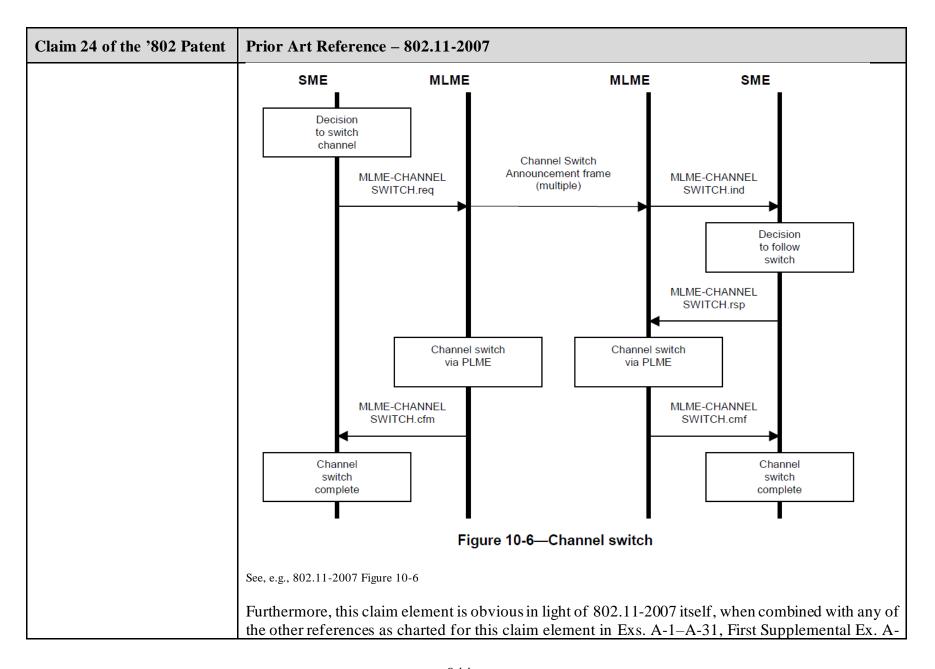


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	See, e.g., 802.11-2007 § 17.3.8.1
	17.3.8.3.1 Operating frequency range
	The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded.
	In some regulatory domains, several frequency bands may be available for OFDM PHY-based WLANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11RegDomainsSupported and dot11FrequencyBandsSupported.
	See, e.g., 802.11-2007 § 17.3.8.3.1
	17.3.9.1 Transmit power levels
	The maximum allowable transmit power by regulatory domain is defined in Annex I.
	See, e.g., 802.11-2007 § 17.3.9.1
	17.3.9.6.2 Transmitter spectral flatness
	The average energy of the constellations in each of the spectral lines -161 and $+1+16$ will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines -2617 and $+17+26$ will deviate no more than $+2/-4$ dB from the average energy of spectral lines -161 and $+1+16$. The data for this test shall be derived from the channel estimation step.
	See, e.g., 802.11-2007 § 17.3.9.6.2

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	I.2.2 Transmit power levels			
	The maximum allowable output power by regulatory domain (except in Japan) is shown in Table I.4. The maximum allowable output power by regulatory domain for the U.S. 4.9 GHz public safety band is shown in Table I.5.			
	Table I.4—Tra	nsmit power level by regulator	y domain	
	Frequency band (GHz)	United States (Maximum output power with up to 6 dBi antenna gain) (mW)	Europe (EIRP)	
	5.15–5.25	40 (2.5 mW/MHz)	200 mW	
	5.25–5.35	200 (12.5 mW/MHz)	200 mW	
	5.470-5.725	_	1 W	
	5.725-5.825	(1110 111)		
	Table I.5—U.S. public safety transmit power levels by regulatory don U.S. public safety (mW)			
	Table I.5—U.S. public s	afety transmit power levels by		
		afety transmit power levels by		
	Table I.5—U.S. public s	U.S. public safety (m	(W) 5 MHz	

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	I.2.3 Transmit spectrum mask For operation using 20 MHz channel spacing, the transmitted spectrum shall have a 0 dBr (decibel relative
	to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset, and -40 dBr at 30 MHz frequency offset and above. For operation using 10 MHz channel spacing, the transmitted spectrum shall have a 0 dBr bandwidth not exceeding 9 MHz, -20 dBr at 5.5 MHz frequency offset, -28 dBr at 10 MHz frequency offset, and -40 dBr at 15 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure I.1. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.
	Power Spectral Density (dB) Transmit Spectrum Mask (not to scale)
	Typical Signal Spectrum (an example) -40 dBr
	-30 -20 -11 -9 fc 9 11 20 30 Frequency (MHz)
	Figure I.1—Transmit spectrum mask See, e.g., 802.11-2007 § I.2.3





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	Obviousness Chart, and/or when combined with the knowledge of one of ordinary skill in the art.
	Motivations to combine may come from the knowledge of the person of ordinary skill themselves, or
	from the known problems and predictable solutions as embodied in these references. Further
	motivations to combine references and additional details may be found in the Cover Pleading and
	First Supplemental Ex. A-Obviousness Chart.